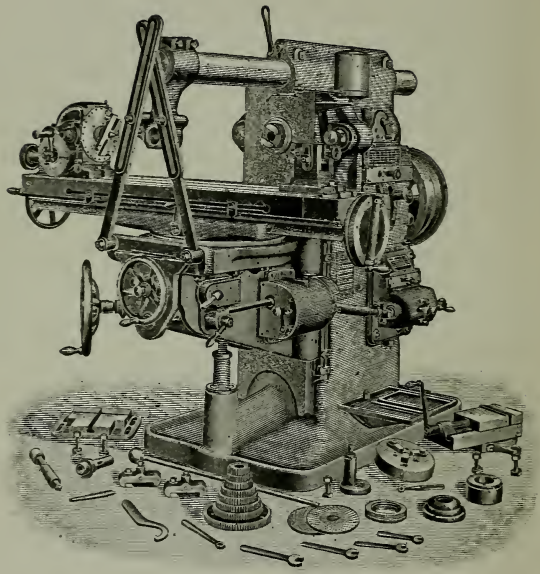
A HANDBOOK

FOR

APPRENTICED MACHINISTS

Fritz

1937



A HANDBOOK

FOR

APPRENTICED MACHINISTS.

EDITED BY

OSCAR J. BEALE.

THIRD EDITION.

PROVIDENCE, R. I., U. S. A.
BROWN & SHARPE MFG. CO.

PREFACE.

This book is for learners in the use of machine tools, and is the outgrowth of the needs of the Brown & Sharpe Mfg. Co. in the instructing of apprentices. It was felt that there is too much uncertainty in depending upon oral instruction to impart the information in some details which every apprentice is entitled to receive. An experimental edition of this book was printed, and proved useful; the present edition is carefully revised and enlarged, with the hope that it will be still more useful.

A book can hardly be of much help in attaining the skill that is so necessary in mechanical pursuits. Skill is largely a matter of labor and of time,—of unwearied labor and much time. The world of to-day asks, "What can you do?" The answer to this question also answers all that the world cares to ask about what you know.

There are, however, important points in the use of machine tools that are more matters of knowledge

than skill. This book aims to present a few of these points, which should be learned early and remembered late. It comprises hints in the care of machine tools; an explanation of terms pertaining to screw threads; instructions in the figuring of gear speeds and pulley speeds, as well as the figuring of change gears for screw cutting; a chapter on angles and working to angles; a chapter on circular and straight line indexing, and the subdividing of screw threads.

It does not aim to take the place of the excellent engineer's pocket books, already published, some one of which an apprentice should obtain. He should also subscribe for a mechanical paper.

Besides skill, an important element of success is a readiness in applying to practical purposes what can be learned in books and in periodicals.

CONTENTS.

INTRODUCTION.

The learning of a trade is a serious affair; it does not come easy to most boys.

In learning, as well as ever afterward, it is important to attend to what is going on at the present moment; this is the way to avoid the loss of work, and perhaps the loss of a hand or an eye.

If a machine is set wrong, it may spoil valuable work.

The effect of some mistakes may not always be immediate and severe. A pupil may go to recitation without having studied his lesson, and yet be able to answer the questions put by the teacher. In a machine shop, however, if a workman makes a mistake when running a machine the machine never excuses him. If he gets in the way of a machine he is always punished, and often with extreme severity. A man stopped a planer by half shifting the reversing belts, without stopping the counter-shaft overhead. He bent over to look into the place where he had just been planing; his leg pushed the operating lever, the planer started, and the tool plowed deep through his skull.

Care of Self. Want of care does more damage than want of knowledge; hence, care and knowledge should be well commingled. It is easier to form a habit than to break one off; therefore, we should strive to form correct habits.

Before beginning to learn machine making we should learn that it is dangerous to lean against a machine that is running, and that it is important to keep a proper distance from any mechanism that is in motion, or likely to be set in motion. It is sometimes convenient to place one's hand upon a moving piece, but before doing so one should know the direction of the motion, and the place touched should not be the teeth of a gear nor the teeth of a cutter. If one touches a piece supposed to be moving south when in reality it is moving north, one's hand may be seriously injured.

In touching a belt that is running, the hand should be kept straight, and should touch the belt only upon its edge; if the fingers are bent they may be caught between the belt and the pulley.

Never put your fingers in the way of a machine for fun; in short, never play with a machine at all, for it will not stand a joke.

It is dangerous to set a lathe tool when the work is running, and still more dangerous to set a planer tool.

Care of Machine. Having given our young machine maker some points for his own safety, we should now like to give him a few for the safety of the ma-

chines themselves. While the machine acts according to a blind and unconscious necessity, apparently with utter fierceness and cruelty, yet it can be very easily injured. Do not allow a tool to run by the work so far as to chuck or bore a lathe spindle. Do not score the platen of a planer. Do not make holes in the table of a drilling machine. Do not gouge the footstock or vise of a milling machine. Do not lay a file or any other tool upon the ways of a lathe; they should be guarded with the greatest care. Do not cut into a lathe arbor.

The running parts of every machine should be oiled at least once a day, and perhaps oftener. Slides and other exposed bearings should be wiped clean before oiling. If you take a machine that someone else has just been running, do not trust that it has been oiled the same day; oil it yourself. If a machine is not properly oiled, it makes a damaging report, it roughs up and stops, often requiring hours to repair before it will run again. After a machine has thus stopped, you need not tell that it has been properly oiled, because nobody will believe you. The evidence of the machine deals only with facts and not with fictions. Even though an abundance of oil has been put into the oil holes, the bearings may not have been properly oiled, because the oilways are plugged up with dirt. It is a bad sign to have the oil remain in the holes without sinking at all, when the machine is running. Every oil hole should be vented so that when oil is forced into one place it can be seen ooz-

ing from another. If an oil hole is not vented the oil may rest on a cushion of air which tends to lift the oil out. If the vent is plugged up it is safer to take the bearing apart and clean the oilways, but sometimes a vent can be cleaned by forcing in naphtha or benzine. If you have been so unfortunate as to have a bearing roughed, the first thing to do is to force in naphtha or benzine; the next thing is to take the bearing apart and have the rough places carefully dressed.

Like many other troubles that have come once, the roughing of a bearing is likely to come again.

It can hardly be expected that one can follow the calling of machine making without soiling one's hands, yet there are grades in grime, and some grades are more offensive than others. From a mechanic's point of view, one machine may be dirty while another is clean. There are workshops that are kept in a more healthful condition than some dwelling houses.

Have Spoiled Pieces Replaced. A mistake that injures a piece of work should be reported as soon as known; for it is extremely annoying and unnecessarily expensive to replace spoiled pieces after they have been turned in as being right.

Tools and Work. Some workmen arrange their tools so that they can be easily reached, and do not let files destroy one another by throwing them together. The use of a monkey-wrench for a hammer indicates poor taste; and to jam a piece of fin-

ished work in a vise or under a set-screw proves that a man lacks in mechanical ability; whatever else he may succeed in, it is very unlikely that he can ever become a good workman. Any man to whom a bad job is not a lasting mortification, shows himself deficient in self-respect. A long job may be soon forgotten; a bad one never.

Rust. Everything made of iron or steel is liable to rust, and rust once begun continues to destruction if left to itself. A common preventive of rust is a coating of some oily substance. Before applying the coating the piece to be protected must be quite clean, because any rust under the coating is sure to increase. The perspiration of some persons rusts iron and steel to such an extent that it forms a serious objection to their touching anything that is finished.

Attention to Instructions and Drawings. The strictest attention should be paid to the instructions of the foreman, and the drawings should be clearly understood before a piece of work is begun. To insure the correctness of our drawings, they are examined and checked before they are passed into the workshop. Attend to what is written upon a drawing; work by the words as well as by the figures.

In making a new machine, examine and measure the castings and the forgings before cutting into them, in order to avoid the disturbing surprise that may come from a tardy discovery that a blank will not work out.

If a job that was begun by another workman is given you to be finished, it is better to discover his mistakes, if there be any, before you begin than afterward. Before you have done any work on a job it is easier also to make somebody believe that you have discovered a mistake than it is afterward. When a job is almost done do not be too sure that it is coming out right; be just as careful at the finish as at the start.

An instance showing the importance of a little forethought will be understood by Figs. 1, 2, 3, and 4.

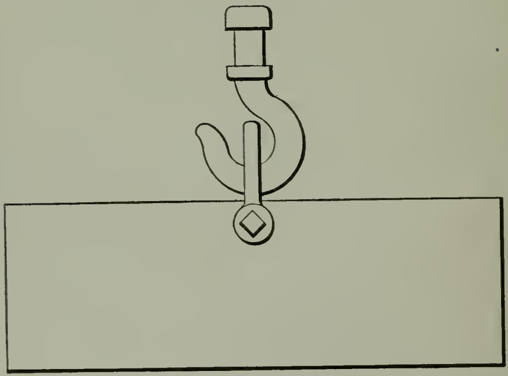


Fig. 1

C Clamp or Grip. Sometimes a convenient way, in raising and handling a piece, is to grip it with a C clamp and then to hook the clamp, as in Figs. 1

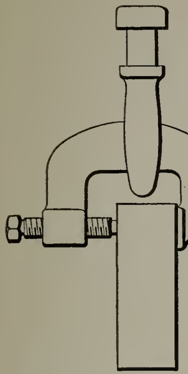


Fig. 2

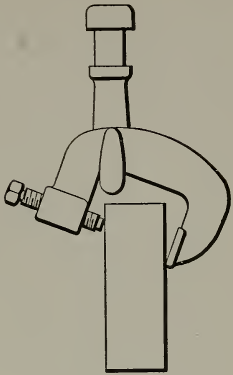


Fig. 3

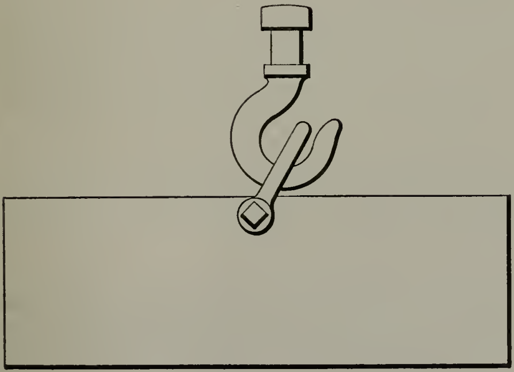
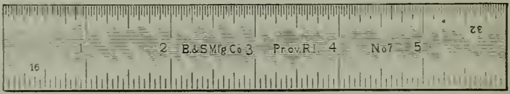
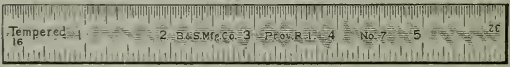


Fig. 4

and 2. This method can not be recommended as very safe, and, if followed at all, the clamp must not be cramped as in Fig. 3, nor slanted as in Fig. 4. If cramped, or slanted in either direction, the clamp may slip, and if slanted as in Fig. 4, the hook may swing it up and loosen the screw. By failure to attend to these points, a clamp lost its grip and a workman lost his thumb.

The importance of machine making is very great, and is not likely to become less in the future; the comfort, convenience, and safety of every person depend more or less upon well-made machinery. Defective and ill-cared for machinery is an element of inconvenience and loss, and sometimes of danger that may lead to a tragedy.





Chapter I.

Centreing and the Care of Centres.

A solid piece that is to be turned in a lathe usually has centre holes that form bearings for the lathe centres, as indicated in Fig. 8. Heavy pieces are sometimes centred by guide marks equidistant from the outside, which can be drawn in a variety of ways, two of which are shown in Figs. 5 and 6. The marks in Fig. 7 were drawn as in Fig. 6. These marks guide the centre punch in pricking for the centre holes, which are then drilled and countersunk in a hand lathe. Light pieces are drilled central and countersunk in a centreing machine.

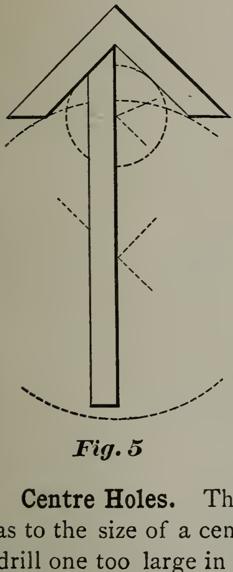


Fig. 5

Centre Holes. There is no special need of a rule as to the size of a centre hole; still it is well not to drill one too large in a small piece; thus a $\frac{3}{32}''$ hole

Fig. 6

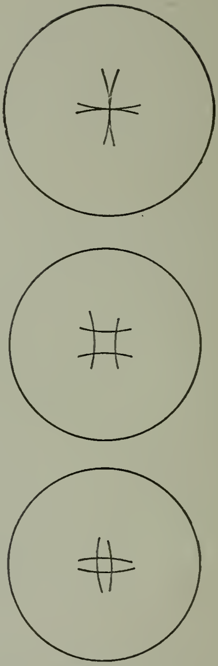


Fig. 7

is too large to drill in a ⅛″ piece. If an arbor is often used on the centres, it is well to round the edges of the centre holes as shown in Fig. 9, also to have a recess around the hole as shown at a, a.

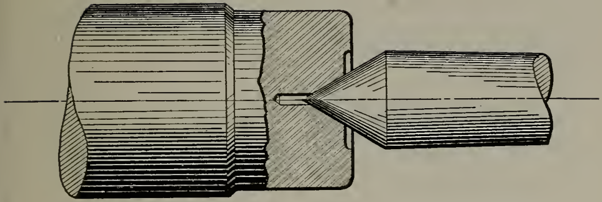


Fig. 8

It is of the highest importance that a centre have a good bearing, that it be kept well oiled and free from dirt and chips. Figs. 10 to 15 are so clear that they need little or no explanation; they are all bad cases, and should never be allowed to exist. Fig. 15

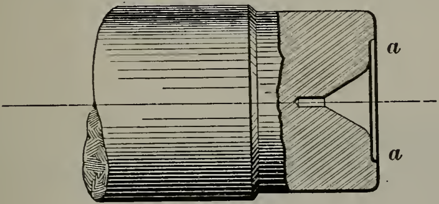


Fig. 9

has been injured by driving a centre against one side of the centre hole, thus throwing out a projection that will make the work run out of true. If a crooked

piece, Fig. 16, is drilled and then straightened, the centre holes will be like Fig. 17; they will wear unevenly and throw the part of the piece that is finished first, out of true with the part that is finished last. For very accurate work the centre holes should be trued after the piece is straightened. The centre holes in hardened arbors should be lapped, after the arbors are hardened.

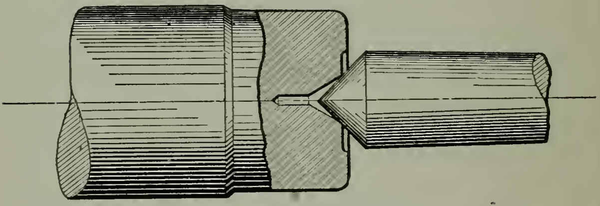


Fig. 10

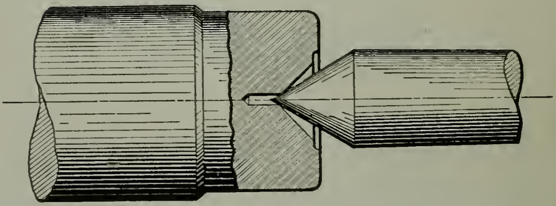


Fig. 11

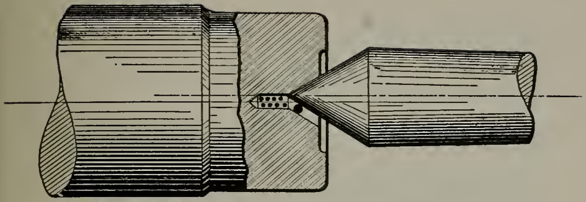


Fig. 12

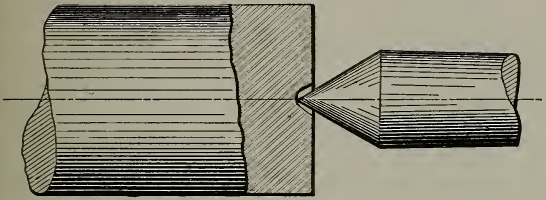


Fig. 13

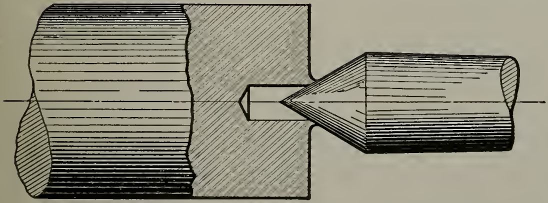


Fig. 14

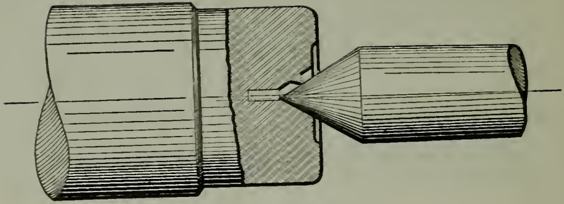


Fig. 15

Centre and Arbor True. Before beginning to turn any accurate piece of work, always make sure that the live centre runs true. Never take it for granted that the centre is true. Before beginning to use an arbor, make sure that it is true enough for your purpose. For accurate work, the arbor should be tested after being forced into the piece to be turned, because an arbor may be straight before it is forced into a hole and not be straight when in the hole.

Angle for Centres. A common angle for a centre is 60°, and a finished centre hole should have the same angle as the centre. In arbors that are to be hardened it is well to countersink the holes 59°, so that they can be easily lapped into good 60° holes after hardening. The lap can be made of copper, of the same shape as a centre, and used with emery and oil.

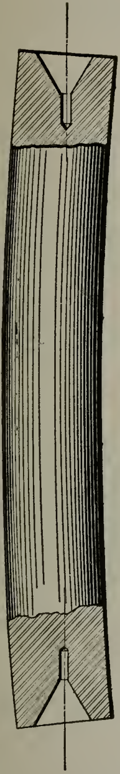


Fig. 16

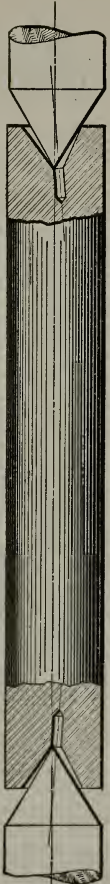


Fig. 17

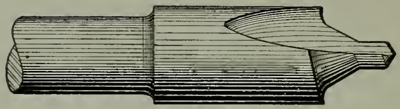
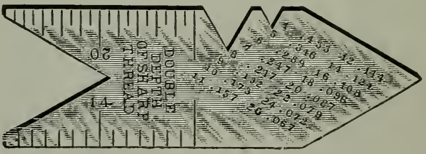


Fig. 18

Centre Drill and Countersink. The combination of a centre drill and countersink, Fig. 18, saves time and insures the hole's being central with the countersinking. These drills were used by us about 1865 for centreing needle bars, and as our general machine business increased, their use extended to other parts of our works.



Chapter II.

Turning. Reading a Drawing. Measuring. Lacing a Belt.

After pieces have been centred and straightened, they are taken to the lathe to be turned. Our first care should be for the lathe; the ways and slides should be wiped clean, and all the bearings should be thoroughly oiled. The live centre should run true. For very accurate work a live centre may have to be trued in place. If the centre is taken out and put in again, after being trued up, it should be in the same position as it was when trued up.

Setting Centres. When straight work is to be turned, the centres can be set in line by bringing them close together and adjusting the dead centre; but this way of adjusting will not insure the lathe's turning straight. The straightness can be more accurately tested by measuring a piece after taking off the first chip.

A modification of this method is to turn a short place near the dog; and, without changing the setting of the tool, take the piece off the centres, bring the tool back to the dead centre, then putting the piece

on the centres again, turn a place at the dead centre, and measure the two turned places. The setting of the centres can be tested also by an indicator held in the tool post and run along a straight bar on the centres. In the absence of an indicator a tool can be held in the tool post and the test made with a piece of paper between the tool and the bar.

Height of Tool. Generally the cutting edge of the tool is set about the same height as the centres, but this is not important when turning straight; sometimes the tool cuts better when the edge is above the centre,—it should never be below the centre.

When turning tapering, the tool must be the same height as the centres; if not of the same height, the taper will vary, and, theoretically, the sides of the tapering piece will be hollowing on the outside, while in a hole the sides will be rounding. The tool might have to be considerably above or below the centre to make the curved sides noticeable, but any variation in height makes an appreciable difference in the taper.

Reading a Drawing. There are not many things in mechanical pursuits that lead to more trouble than the incorrect reading of a drawing. Almost every incorrect reading of a drawing comes from want of care.

One of the commonest sources of error is to mistake a dotted line for a full line. Dotted lines are drawn to represent three things: first, a part that is

below the surface ; second, a piece that is to be taken off; third, the different positions of a moving piece. In Fig. 19 the dotted lines pertain to a slot, and the

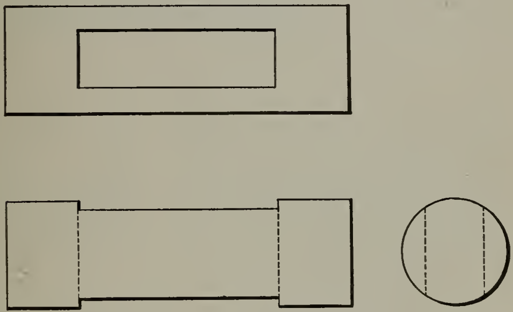


Fig. 19

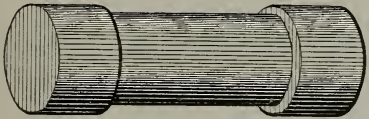


Fig. 20

blank must not be necked in like Fig. 20. Before the slot is cut, the blank for Fig. 19 looks like Fig. 21.

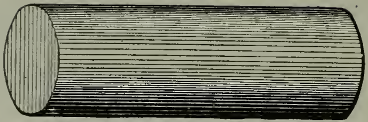


Fig. 21

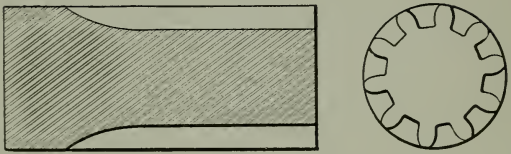


Fig. 22

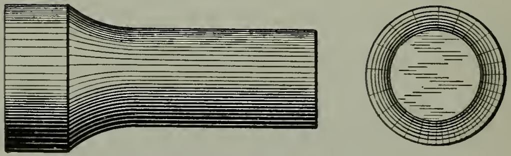


Fig. 23

Section Lines. Section lines do not always represent the full size of a piece. In Fig. 22, teeth are cut a part of the length; the blank for this must not be like Fig. 23, but must be like Fig. 24.

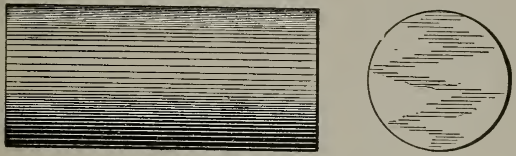


Fig. 24

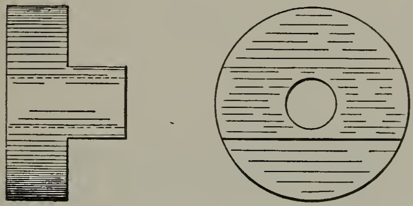


Fig. 25

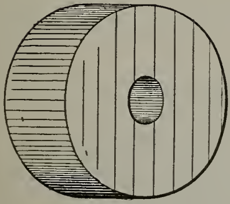


Fig. 26

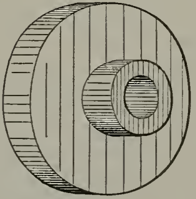


Fig. 27

The distance between two lines does not always represent the size of a piece across the largest way; thus, to make Fig. 25, the blank must be like Fig. 26, and not like 27. Fig. 19 is also a case in point.

The outline of a piece in one view is not always like that in another view; thus the piece with the blunt wedge-shaped end, Fig. 28, should be blanked out like Fig. 29, and must not be like Fig. 30.

Direction of Lines. There is a class of mistakes that consists in not seeing in which direction a line inclines. The clutch, Fig. 31, is shown in section, and the teeth should not be cut like Fig. 32, in which the teeth are shown in full. In Fig. 31 we see the inside of the teeth, while in Fig. 32 we see the outside. In Fig. 33 there is no excuse for having the hole tapered the wrong way; the drawing is plain enough. Mistakes of this class may occasion much greater loss than the ones in Figs. 19 to 30 already spoken of.

A convenient style of section lining is shown in Fig. 34.

Figs. 35 and 36 suggest a way of measuring at a place that cannot be reached with a pair of calipers alone.

Measuring Work. Do not try to caliper a piece of work while it is in motion.

Do not force a standard gauge when the fit is too tight. If these precautions are not taken, the lifetime of an expensive measuring instrument may be very short.

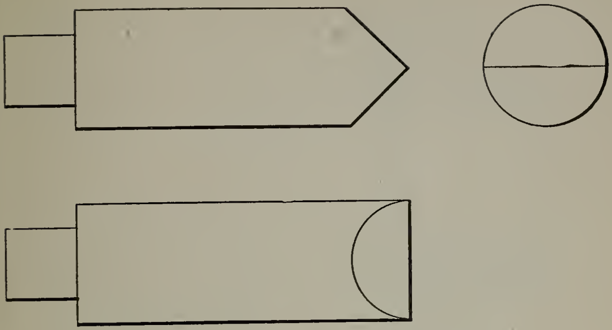


Fig. 28

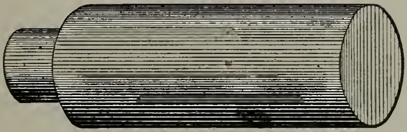


Fig. 29

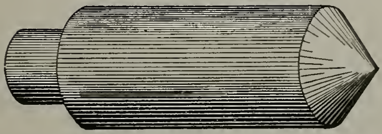


Fig. 30

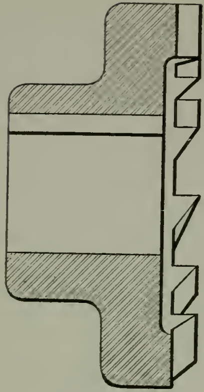


Fig. 31

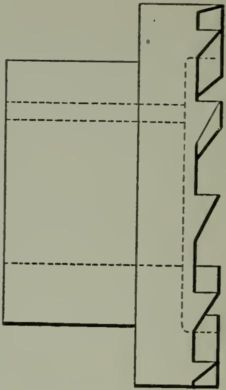
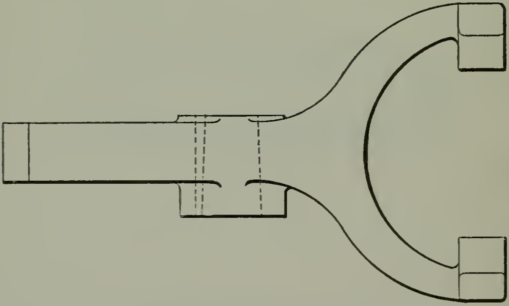


Fig. 32



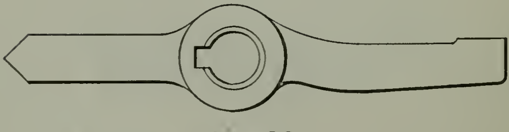
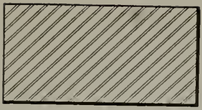
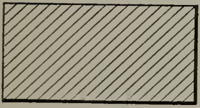


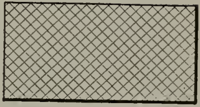
Fig. 33



Wrought Iron or Steel.



Cast Iron.



Brass or Bronze.

SECTIONS OF MATERIALS.

Fig. 34

Lacing Belts. Belts laced as in Figs. 39 and 40 have worked well in practice. To lace a belt in this way we begin as in Figs. 37 and 38, and finish as in Fig. 39, these three figures showing the same side of the belt. The other side of the belt is shown in Fig. 40. By passing the lacing through between the ends of the belt, as shown in Fig. 41, the joint is made quite flexible, so that it can run over a small pulley; before lacing in this-way the corners of the ends of the belt should be rounded. Fig. 42 shows how a belt can be laced and have only one thickness of lacing at any one place.

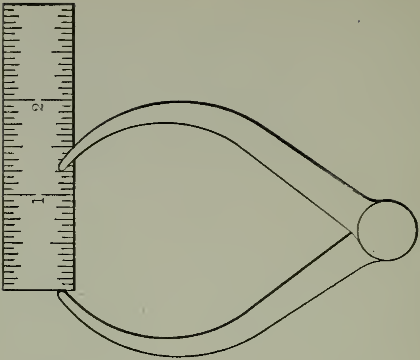


Fig. 36

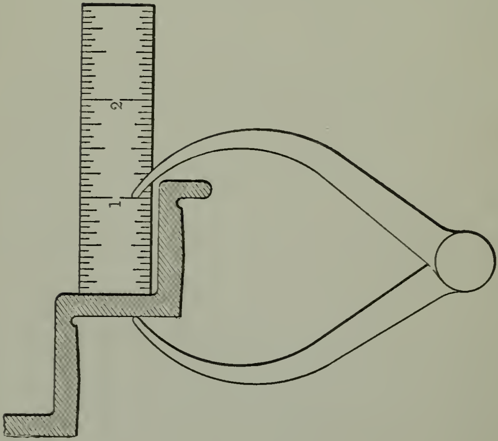


Fig. 35

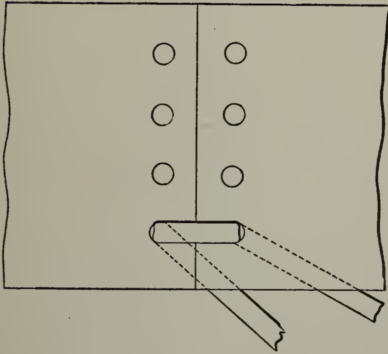


Fig. 37

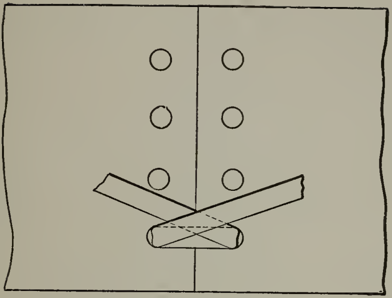


Fig. 38

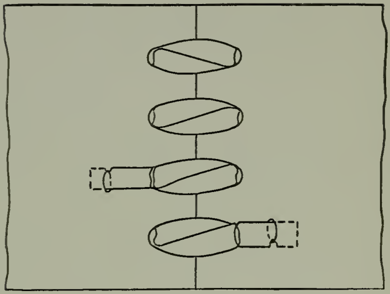


Fig. 40

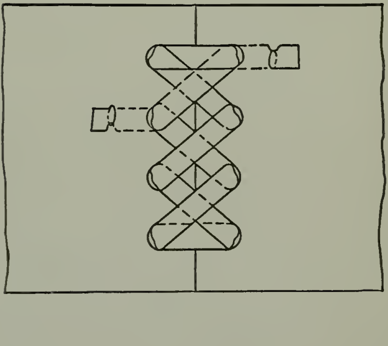


Fig. 39

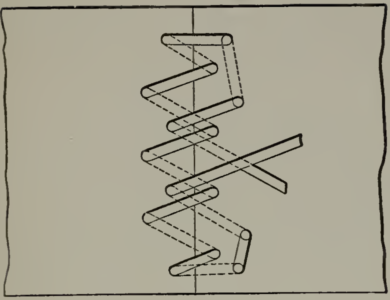


Fig. 42

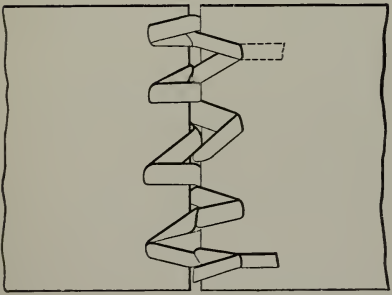


Fig. 41

Chapter III.

Signs and Formulas.

$'$ Sign of feet; as, $9'$ signifies nine feet.

$''$ Sign of inches; as, $3''$ signifies three inches.

When all the sizes on a drawing are in inches, the sign of inches is often omitted.

$=$ Sign of equality; as, $12'' = 1'$ signifies that 12 inches are equal to one foot.

$^\circ$ Sign of degrees; as, 30° signifies thirty degrees.

$'$ Sign of minutes; as, $60' = 1^\circ$; that is, sixty minutes are equal to one degree.

$''$ Sign of seconds; as, $60'' = 1'$; that is, sixty seconds equal one minute.

$+$ Sign of addition; read "plus," or "added to"; $8 + 6 = 14$; that is, 8 plus 6 equals 14, or 8 added to 6 equals 14.

$-$ Sign of subtraction; read "minus" or "less"; as $8 - 6 = 2$; that is, 8 minus 6 equals 2, or 8 less 6 equals 2.

$\times$ Sign of multiplication; as $7 \times 6 = 42$; that is, 7 multiplied by 6 equals 42.

. Another sign of multiplication; as, $3 \cdot 5 = 15$.

Where there are several multipliers or factors we can read *the continued product of*, and not say the words, "multiplied by"; as $3 \times 4 \times 7 \times 9 = 756$ is read, "the continued product of 3, 4, 7, and 9 is equal to 756." When the numbers to be multiplied are represented by letters, the sign of multiplication may be omitted; thus, the continued product of numbers represented by R, D, and d is written RDd. $1.155A = D$ indicates that A multiplied by 1.155 is equal to D.

$\div$ Sign of division; read, "divided by"; as $42 \div 6 = 7$; that is, 42 divided by 6 equals 7.

Sometimes, in place of the dots, the number divided is written above the line, and the number that divides is written below; thus, $\frac{98}{7}$ is read, "ninety-eight divided by 7"; $\frac{9}{12} = \frac{3}{4}$ indicates that 9 divided by 12 equals three-fourths.

: An abbreviated sign of division, which is employed in expressing a ratio; thus, $4 : 5$ signifies 4 divided by 5, and is read, "the ratio of 4 to 5."

: : Another sign of equality, which is employed to express equality of ratios; thus, $28 : 42 :: 2 : 3$ is read, "28 is to 42 as 2 is to 3." This can be expressed also by $\frac{28}{42} = \frac{2}{3}$.

π The Greek letter *pi* represents the ratio of the circumference of a circle to its diameter. $\pi = 3.1416$; that is, multiply the diameter by 3.1416 and the

product is the circumference. If we take $\pi = 3\frac{1}{7}$, we have an error of a thousandth of an inch in three inches.

Instead of writing "revolutions per minute" in full, it is sufficient to write "rpm."

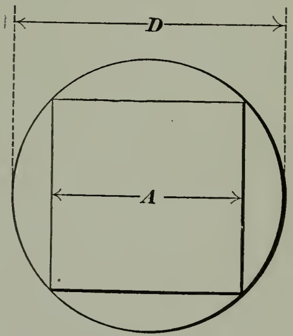


Fig. 44

Turning to Finish Square. In Fig. 44, 1.414A = D; that is, in turning a piece to be milled down square, *multiply the side of the square by 1.414, and the product is the diameter to turn the piece.*

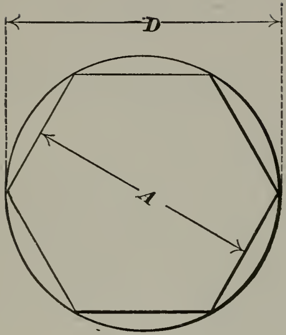


Fig. 45

Turning to Finish Hexagonal. In a six-sided piece, Fig. 45, $1.155A = D$.

Example: Of what diameter must a piece be, in order to have stock enough to mill down six-sided to $1\frac{1}{4}''$ across the flats? $1\frac{1}{4}'' \times 1.155 = 1.444''$, the diameter of the blank.

Formulas will express more on a square inch of paper than words on a whole sheet. The meaning of formulas is clearer also, and they can be understood more quickly than words.

Chapter IV.

Drilling. Counterboring. Tapping. Cutting Speed.

Grinding Drills. If a drill has more than one cutting lip, the lips should be ground to cut equally. Unless a drill is ground right it will cut larger than itself. If the diameter of the hole is to be exact, it is well to drill into a trial piece in order to know what the drill will do.

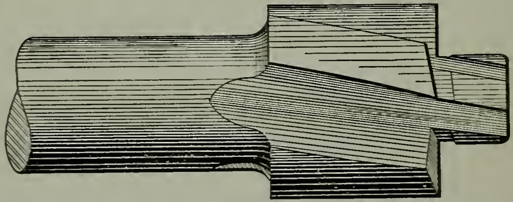


Fig. 43

Counterbore. The teat of a counterbore, Fig. 43, should be oiled. If it is not oiled it may rough up and be destroyed. Before counterboring into rough cast iron, it is sometimes well to break up the scale with a cold-chisel.

Taps. In threading a hole with two or more taps, one may not track with another. The thread is then said to be split. This is a bad job. A workman will not be guilty of splitting a thread when he realizes the danger of so doing and tries to avoid it. In tapping by hand and with a jig, the tap should reach the work before it is turned.

A drill broken off in a hole is a bad case, but the end of a tap in a hole is a disaster that destroys much more than the tap. A good workman very seldom has these cases to dispose of.

Cutting Speeds and Feeds. Much of the work in a machine shop consists in cutting off chips. The speed and correctness with which they are cut off has much to do with a workman's success. The speed may be limited by: the breaking of a tool; the wearing of a cutting edge; losing the temper of a cutting edge; a weak machine drive; the work's being so weak as to spring.

To avoid breaking a tool, do not start a machine backward. To avoid undue wear of a cutting edge, cleave off the chips rather than pulverize; to cleave off chips, the angle of the cutting edge must not be obtuse. To avoid loss of temper, keep cutting edges sharp; to try to push off stock with a dull edge wastes a tool faster than to grind often and keep sharp. Do not let a driving belt become too loose to drive. If a piece of work is weak, it must be either humored or supported.

Speed of a Planer Table. An average cutting

speed for planing steel is 20 feet per minute; and for planing cast iron, 26 feet per minute.

The Speed for Turning and for Milling soft steel or wrought iron, is about 48 feet per minute. For cast iron the speed can be about 60 feet per minute. Soft brass is often cut at the rate of 120 feet per minute, when using ordinary tool steel. The speed of cutters, made of High Speed Steel, cannot be governed by any definite rules but, in a general way, the following surface speeds are found satisfactory: For Brass, 200′ per minute; Cast Iron and Steel, 100′ per minute. The tendency in everything, except finishing cuts, is towards Fast Speeds and relatively Fine Feeds.

The surface speed in turning cannot be maintained at quite so high a rate as in milling.

Figuring the Revolutions per Minute. To obtain a cutting speed of a given number of feet per minute, it is convenient to have a constant or dividend that can be divided by the diameter in inches of the piece to be turned, the quotient being the rpm. When the diameters are equal, a milling cutter runs at about the same rpm as a piece to be turned.

For 48 feet per minute, we can use 184 as the constant or dividend.

Examples: How many rpm for 5 inches diameter to cut 48 feet per minute?

$$184 \div 5 = 36.8 \text{ rpm or about } 37.$$

For 48 feet per minute we have also:

For 4 inches diameter $184 \div 4 = 46$ rpm.
For 1 inch diameter $184 \div 1 = 184$ rpm.
For ¼ inch diameter $184 \div \frac{1}{4} = 736$ rpm.

The following table gives constants for a few other speeds:

For	26	feet	per	minute,	constant	100
"	35	"	"	"	"	134
"	42	"	"	"	"	161
"	48	"	"	"	"	184
"	60	"	"	"	"	230
"	120	"	"	"	"	460

Example: It is required to run a ⅛ inch drill about 60 feet cutting speed per minute. What must be the rpm?

The constant for 60 feet is 230.
$230 \div \frac{1}{8} = 1840$ rpm.

An Average Feed for Turning soft steel and wrought iron, the first or roughing chip, is 1 inch to 50 turns; and for cast iron, 1 inch to 25 turns.

A sizing chip is cut from pieces that are to be smoothed with a file. The average sizing or finishing feed for steel and wrought iron is 1 inch to 100 turns; and for cast iron, 1 inch to 75 turns.

For work that is to be ground, the sizing chip can be as coarse as the roughing chip.

Planer Chips are about the same size as lathe chips.

The variation between different feeds is very wide —much wider than the variation in cutting speeds. In planing cast iron, the feed for finishing surfaces that are not to be scraped is often ½ inch to 1½ inches at each chip. In turning, the chips are some-

times equally coarse. To finish with so coarse a chip, the tool must conform to the surface. For planing surfaces that are to be scraped, the average feed is about $\frac{1}{10}$ inch. Work is often more firmly supported on a planer than in a lathe, and, consequently, finishing chips are often wider on a planer than in a lathe.

There is no limit to the width of a chip,—in turning calender rolls it is 5 or 6 inches wide. It is said that a planer has cut a chip 12 inches in width.

A good workman is seldom guided by rules in speeding his machine; he endeavors to learn what the tool and the work will stand, and then selects the safe speed and feed. It should be remembered that the conditions vary; because a certain speed was all that could be attained yesterday, it does not follow that to-day a higher speed cannot be attained. A certain piece of work may require the finest feed of one machine, but not the finest feed of another machine, because all machines do not feed at the same rate.

While a workman's judgement may be correct as to the cutting speed and the feed required, yet it would be well to reduce his judgement to figures for a few cases. The "judgement" of every workman in a tool making department was to use the finest feed in his lathe, which required a 28 tooth gear on the spindle stud. The foreman took away every 28 tooth gear and put on the next larger, a 35 tooth gear. The twenty-five per cent. increase in feed was not

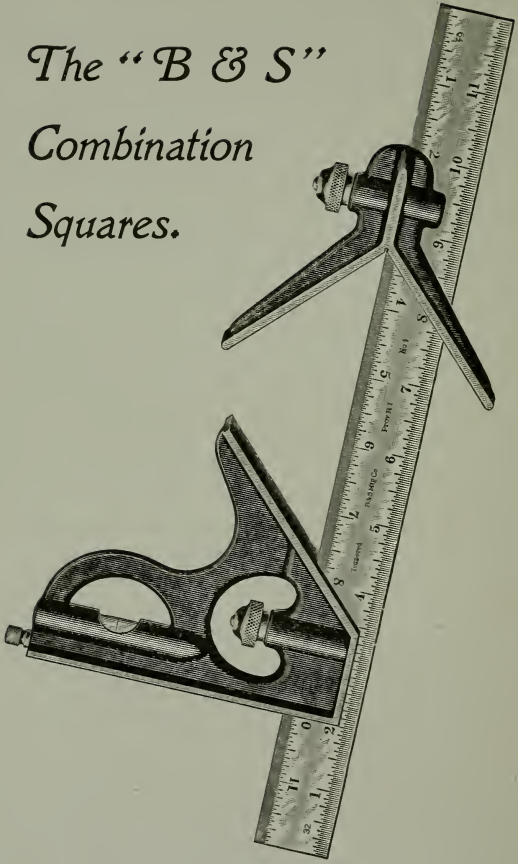
discovered by any of the workmen for many months, and it would not then have been noticed if one of the workmen had not wanted to thread a screw requiring the small gear.

The cutting edge of a tool should not be moved upon a piece of work unless the edge presses against it hard enough to cut.

A cutting edge should never drag backward.

If the edge drags or rubs without cutting, it is rapidly dulled and worn away.

The "B & S" Combination Squares.



Chapter V.

The Screw and its Parts.

A screw may be formed by grooving a cylinder spirally, as in Figs. 46 and 47, these screws having

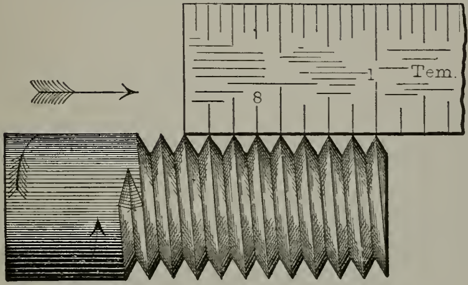


Fig. 46

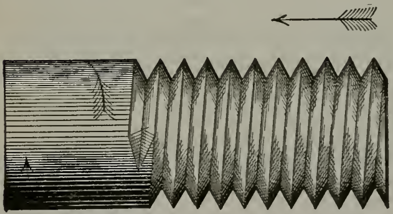


Fig. 47

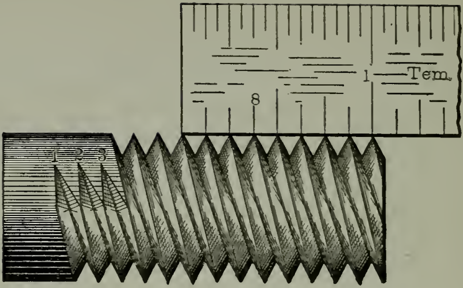


Fig. 48

one groove in each. As a groove winds around, there is an accompanying land, or projection, which is called a *thread.* There may be any number of grooves, and, consequently, any number of threads, to every groove there being an accompanying thread; Fig. 48 has three grooves, 1, 2 and 3.

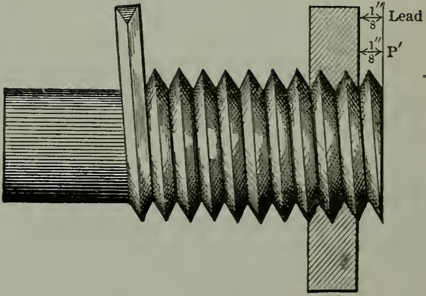


Fig. 49

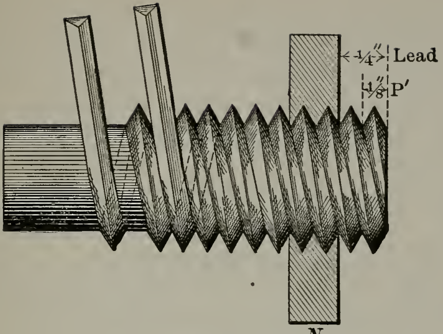


Fig. 50

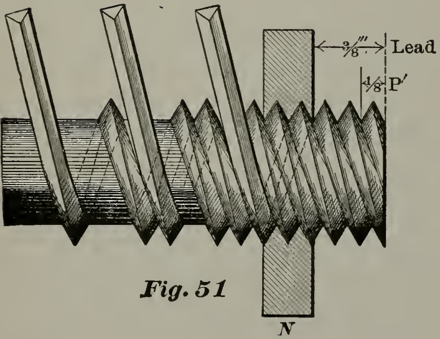


Fig. 51

A screw can be formed also by winding, or coiling a thread spirally around a cylinder, as in Fig. 49. We can wind any number of threads around;

Fig. 50 has two threads; Fig. 51 has three. A screw that has only one thread, like Figs. 46, 47, and 49, is called *single-threaded;* one having two threads, *double-threaded;* three threads, *triple-threaded;* four, *quadruple-threaded.* Single-threaded means threaded once; double-threaded means threaded twice, and so on. Higher numbers than four may be called five-, six-, seven-, eight-threaded, the longer names, quintuple, sextuple, septuple, octuple, not being commonly used. The cutting of the spiral groove, or grooves, is called cutting or threading a screw. Any screw having more than one thread is multiple-threaded.

A Nut is a piece having a threaded hole to go over a screw, as at N, Figs. 49, 50 and 51.

In this chapter we purpose to explain the meaning of four terms pertaining to a screw:

1. Lead.
2. Turns to an Inch.
3. Threads to an Inch.
4. Pitch.

These terms should be thoroughly understood and correctly used. Many mistakes have been made by using one term when another was meant. The lead is not always the same as the pitch;—the turns to an inch are not always the same as the threads to an inch.

We shall also describe a right-hand and a left-hand screw, and a few shapes of threads.

Lead of a Screw. The distance that a thread advances in one turn is called the *lead of the screw.* In a single-threaded screw the lead is equal to the distance occupied by one thread; thus, in Fig. 49, the nut has made one turn, and has advanced one thread upon the screw. In a double-threaded screw the lead equals two threads, as in Fig. 50; in Fig. 51 the lead is three threads, which the nut has advanced in one turn. In general, the lead can be divided by any number of threads, the advance of any one of these threads in one turn being always equal to the lead.

The lead of Fig. 49 $= \frac{1}{8}''$; of 50 $= \frac{1}{4}''$; 51 $= \frac{3}{8}''$.

Turns to an Inch. Divide one inch by the lead, and the quotient is the number of turns that the screw makes to advance one inch; thus, in Fig. 49, $1'' \div \frac{1}{8}'' = 8$ turns to one inch; in Fig. 51, $1'' \div \frac{3}{8}'' = 2\frac{2}{3}$ turns to an inch. The *reciprocal* of a number is 1 divided by that number; the reciprocal of the lead of a screw is the turns to an inch, as just shown. The reciprocal of the turns to an inch is the lead; thus, in Fig. 50, the screw makes four turns to one inch, and its lead is $1'' \div 4 = \frac{1}{4}''$. If a screw does not advance an inch in some whole number of turns, or if it does not advance some whole number of inches to one turn, it is said to have a fractional thread. *In any screw, divide any number of turns by the number of inches occupied by these turns and the quotient will be the turns to an inch.*

Thus, a screw that turns 96 times in 12.005 inches, turns 96 ÷ 12.005, or 7.9967 turns in one inch.

Threads to an Inch. By placing a scale upon a screw, as in Figs. 46 and 48, the number of thread windings, or coils, can be counted; it has been found convenient to call these coils *threads*, and the number of coils in an inch is called the *number of threads to an inch.* In this sense, all the screws, Figs. 46 to 51, are said to have 8 threads to 1″, and the threads to an inch have nothing to do with the number of separate grooves; while the screws, Figs. 46 and 49, have each strictly only one thread, which coils around 8 times in 1″, yet for convenience, we say they have 8 threads to 1″. Fig. 51 is 3/8″ lead, triple-threaded, 2 2/3 turns to 1″, 8 threads to 1″.

Pitch. In connection with a screw, the term *pitch* has been used to denote so many different parts that its meaning is not always clear, so that it is well to employ other terms to denote some of the parts. *Pitch* has been used to denote the advance of a screw thread in one turn; in this sense we prefer the term *lead. Pitch* has also been used to denote the turns to one inch; in this sense we do not prefer pitch; thus, instead of saying the pitch of a screw is 8 to 1″, we should say, the *turns* of the screw are 8 to 1″, or simply, the screw is 8 turns to 1″. As a screw, or worm, is often used to drive a gear, it is well to employ the term *pitch* in the same sense, in connection with a screw, as it is employed in connection with a gear. Hence, *the distance from the centre of one*

thread to the centre of the next thread, measured in a line parallel to the axis, is the pitch of the thread, or the thread-pitch. In Fig. 52 the thread-pitch is at P′.

Divide 1″ by the number of threads to 1″, the quotient is the thread-pitch. The threads to 1″ and the thread-pitch are reciprocals of each other. Instead

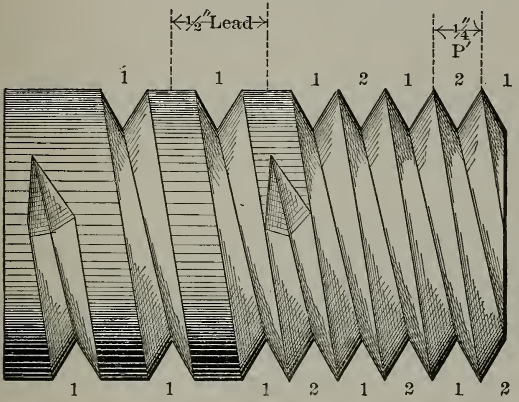


Fig. 52

of writing "pitch" or "thread-pitch," it is sufficient to write simply P′.

Pitch and Lead. The term "pitch of a screw" is still sometimes used in the sense of "lead," but in a machine shop "lead" is much clearer, as it

cannot be confounded with turns to an inch, nor with the pitch of the thread. "Pitch" is also sometimes used instead of "threads;" thus, a screw 8 threads to 1″ might be called 8 "pitch." This use of "pitch" becomes confusing when the real pitch is about 1″, or more than 1″; thus, it is not very clear to say ¾ "pitch," while it is clear to say ¾ of a thread to 1″, and 1⅓″ P′.

It is clear to say ¾″ lead, which is 1⅓ turns to an inch; it is also clear to say ¾″ pitch. When applied to screws, the term "lead" always means the same thing. The lead may be any distance,—a quarter inch, an inch, ten inches, or a yard. If the terms described in this chapter are understood, we shall not confound a ¾″ pitch screw with ¾ of a turn to an inch.

In a single-thread screw, the pitch is equal to the lead. In a double-thread screw, the pitch is half the lead; thus, in Fig. 52, a ½″ lead groove, 1, 1, is first cut, then another groove, 2, 2, is cut, making P′ = ¼″; in a triple-threaded screw the pitch is ⅓ the lead, and so on. Instead of writing single-threaded, it is sufficient to write "single"; instead of double-threaded, "double," and so on.

Right-hand and Left-hand Thread. When the thread inclines so as to be nearer the right hand at the under side, as in Figs. 46 and 48, it is a *right-hand* thread. When the under side is toward the left, as in Fig. 47, the thread is left-handed. Again, when a right-hand screw turns in a direction to move

its upper side away from the eye, as in Fig. 46, the thread appears to move toward the right; while a left-hand thread moves toward the left, as in Fig. 47. R. H. stands for right-hand; L. H. for left-hand.

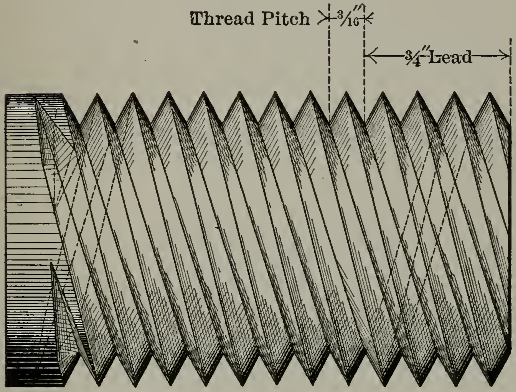


Fig. 53

Fig. 52 is:

> ½" lead, 2 turns to 1", double.
> ¼" P', 4 threads to 1", R. H.

Fig. 53 is:

> ¾" lead, 1⅓ turns to 1", quadruple.
> $\frac{3}{16}$" P', 5⅓ threads to 1", R. H.

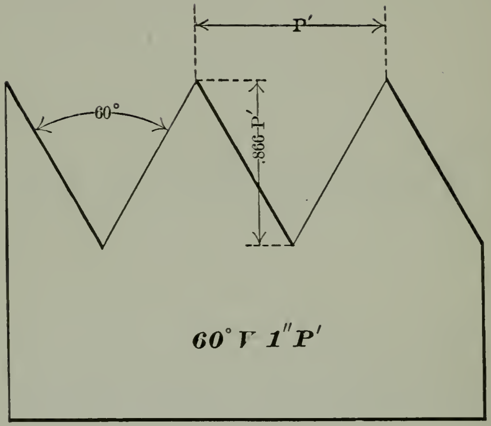


Fig. 54

Shape or Profile of Thread. There are four different shapes of threads in common use:

The 60° V thread, Fig. 54;
The United States standard, Fig. 55;
The Worm thread, Fig. 56;
The Square thread, Fig. 57.

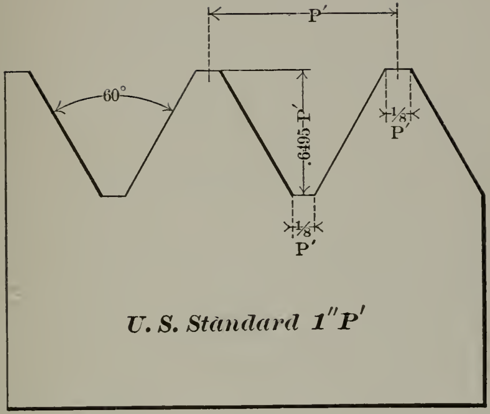


Fig. 55

Depth of Thread. The depth of a 60° V thread is .866 of the pitch, or .866 P′; or what is the same thing, the depth is equal to .866″ divided by the number of threads to one inch. The double depth of the thread is 1.732 P′, or 1.732″ divided by the number of threads to an inch.

Let D = the diameter of the screw;
Let d = the diameter at bottom of thread;
Let N = number of threads to an inch.

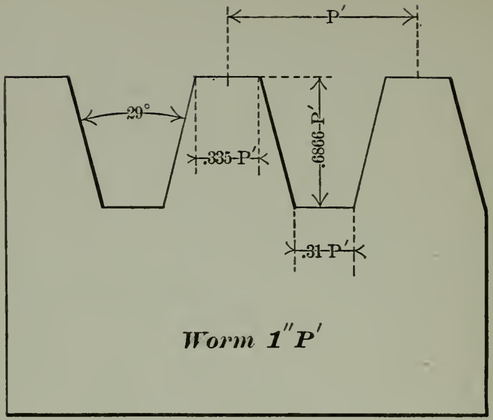


Fig. 56

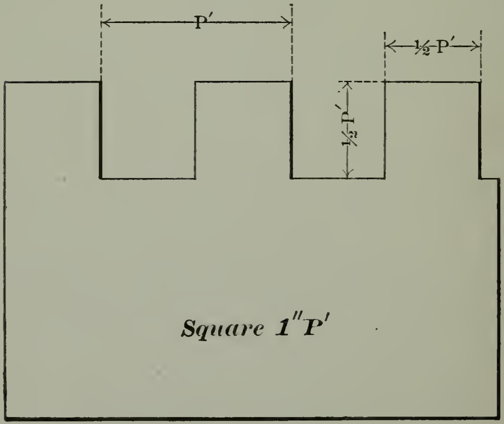


Fig. 57

In a 60° V thread, $d = D - \frac{1.732''}{N}$, from which we have the *rule: The diameter at the bottom of 60° V thread is equal to the diameter of the screw, minus 1.732″ divided by the number of threads to one inch.*

U. S. Thread. The U. S. thread is also 60° angle of sides; the top and bottom are flat, each one-eighth of the pitch, or ⅛ P′, which makes the depth three-quarters that of the 60° V thread, or .6495 P′, $d = D - \frac{1.299''}{N}$; that is, *The diameter at the bottom of a U. S. thread is equal to the diameter of the screw, minus 1.299″ divided by the number of threads to one inch.*

Worm Thread. The worm thread is 29° angle of sides; the top is flat .335 P′ and the bottom .31 P′. The depth is .6866 P′, the double depth being 1.3732 P′. $d = D - \frac{1.3732''}{N}$; that is, *The diameter at the bottom of a worm thread is equal to the diameter of the worm, minus 1.3732″ divided by the number of threads to one inch.*

Square Thread. A square thread has parallel sides; the thickness of the thread and its depth are each one-half the pitch. $d = D - \frac{1''}{N}$; that is, *The diameter at the bottom of a square thread is equal to the diameter of the screw, minus 1″ divided by the number of threads to one ineh.*

In Threading a Tapering Screw, the tool should be set so that the sides of the thread will be symmetrical with the axis; in other words, if a thread tool is ground symmetrical, as it usually is, it should be set square with the centre line of the screw to be threaded.

Chapter VI.

Figuring Gear Speeds.

Tooth Transits. When a gear, Fig. 58, is revolving about its axis, all its teeth, T t, pass a stationary point, P, at every revolution of the gear. When a tooth and a space between two teeth have passed this point, we say that there has been one transit of a tooth. At every revolution of the gear

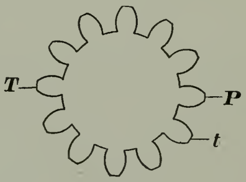


Fig. 58

there are as many tooth transits as the gear has teeth; multiply the number of teeth by the revolutions, and the product will be the number of transits; divide the number of transits by the number of teeth in the gear, and the quotient will be the revolutions of the

gear. Thus, when there have been sixty transits of a 12-tooth gear, it has made five revolutions.

Now, if two gears, Fig. 59, run with their teeth meshed, there is the same number of tooth transits in each gear; hence, if we know this number, we can figure the revolutions of each gear by dividing

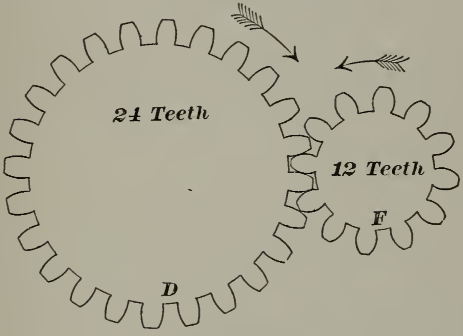


Fig. 59

the transits by the teeth in the gear. Thus, for 48 transits, the 24-tooth gear D makes $\frac{48}{24} = 2$ revolutions, and the 12-tooth gear F, $\frac{48}{12} = 4$ revolutions.

Hence when two gears run in mesh, their relative speeds are in the inverse ratio of the numbers of their teeth, the gear with the less number of teeth running at the higher speed.

Driver and Driven. One gear is usually a driver, and the other a driven or a follower, the driver moving or driving the follower. Two gears that run together are often called a *pair* of gears, and either gear is a mate to the other.

Let D = the number of teeth in the driver.
Let F = the number of teeth in the follower.
Let R = the number of revolutions of the driver.
Let r = the number of revolutions of the follower.

Then DR, the product of the teeth in the driver by its revolutions, equals the tooth transits of the driver, and Fr = the tooth transits of the follower.

DR = Fr; that is, the tooth transits of the driver are equal to those of the follower.

From DR = Fr we have $\frac{DR}{F} = r$, and $\frac{Fr}{D} = R$, from which we have the rule for the relative speeds, or revolutions, of the two gears in mesh: *Multiply the teeth of one gear by its revolutions, and divide the product by the teeth of the other gear; the quotient is the revolutions of the other gear.*

Examples: How many revolutions does the 12-tooth follower F make to five revolutions of the 24-tooth driver D? $\frac{24 \times 5}{12} = 10$ revolutions.

Given, a driver having 98 teeth and its follower 42: how many revolutions will the follower make to one revolution of the driver? $\frac{98}{42} = 2\frac{14}{42}$, or $2\frac{1}{3}$.

How many revolutions of the driver will drive the follower one revolution? $\frac{42}{98} = \frac{3}{7}$ of a revolution.

Number of Teeth for Revolution. If it is required to figure the number of teeth that a gear must have in order to make a certain number of revolutions in proportion to its mate, we *divide the tooth transits of the mate by the required revolutions, and the quotient is the number of teeth that the gear must have.*

Examples: How many teeth must a follower have in order to make three revolutions while a 96-tooth driver makes one? $\frac{96}{3} = 32$ teeth in the follower.

How many teeth must a gear have to revolve 16 times, while a 60-tooth mate revolves 12 times? In 12 revolutions of the mate there are tooth transits equal to 12×60; dividing by 16, we have $\frac{12 \times 60}{16} = 45$ teeth in the gear.

Train of Gears. When two gears mesh, as in Fig. 59, one revolves in the opposite direction from the other. Three or more gears running together, as in Fig. 60, or Fig. 61, are often called a *train* of gears. In a train of spur gears, Fig. 60, one gear I, which is called an *intermediate* gear, meshes with the two other gears D and F, and compels the revolutions of D and F to be both in one direction, while the intermediate revolves in the opposite direction. The intermediate does not change the relative speeds of D and F, so that they can be figured as explained on page 60. An intermediate gear is also called an *idler*.

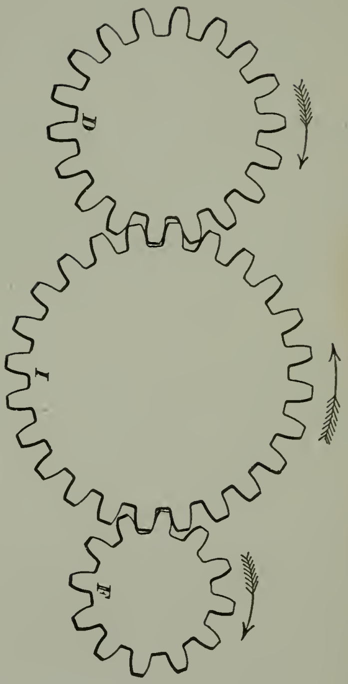


Fig. 60

In Fig. 61 a gear D meshes with F; F is fast to d, which meshes with f.

Let D = the number of teeth in D
Let F = the number of teeth in F
Let d = the number of teeth in d
Let f = the number of teeth in f
Let R = the revolutions of D
Let r = the revolutious of f

Revolutions. Let D be the driver, which will make F a follower; d will be another driver and f another follower. To figure the number of revolutions of f to any number of revolutions of D, we can go step by step, as on page 60. DR, the product of the teeth in D by its revolutions, equals the tooth transits of D, which divided by F gives the revolutions of F: the revolutions of F multiplied by d equals the tooth transits of d, which divided by f equals the revolutions of f. It is sometimes necessary thus to figure step by step in order to obtain the speed of every gear in the train, this operation being applicable to a train of any number of gears arranged as in Fig. 61. If, however, we wish to know only the revolutions of the last follower f, when we know the revolutions of the first driver D and the teeth in all the gears, the operation is shortened by the use of the formula $\frac{RDd}{Ff} = r$, from which we have the rule: *Take the continued product of the revolutions of the first driver and all the driving gears, and divide it by the continued product of all the followers; the quotient is the number of revolutions of the last follower.*

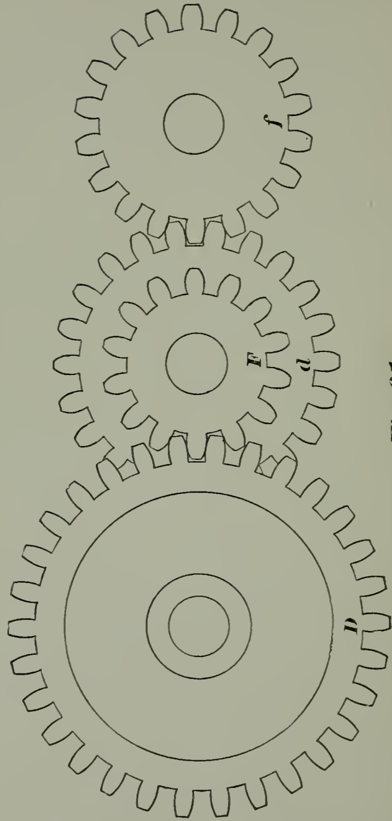
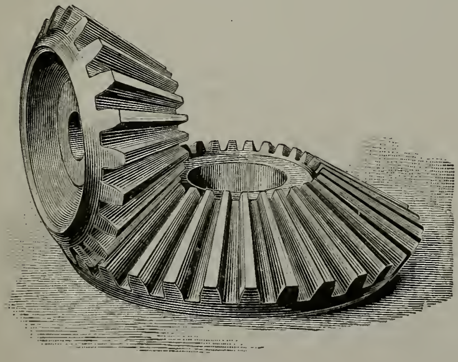


Fig. 61

It is well to remember this principle in Fig. 61: *The continued product of the revolutions of the first driver and the teeth of all the driving gears is equal to the continued product of the revolutions of the last follower and the teeth of all the driven gears.* The formula for this is RDd = rFf. This principle is true for any number of driving and driven gears, and it is the foundation of all the rules given in this chapter. If only this formula be thoroughly understood and committed to memory there will be no need of committing the rules of this chapter to memory, because this formula contains them all.

The position of a driver does not affect the speed of the last follower. Thus either driver can be placed at D or at d, Fig. 61. Either follower can go on at F or at f without affecting the speed of the last follower.



Chapter VII.

Figuring Pulley Speeds.

A common way for one shaft to drive another is by means of a belt running upon two pulleys, one on the driving shaft and the other on the driven, as in Fig. 62.

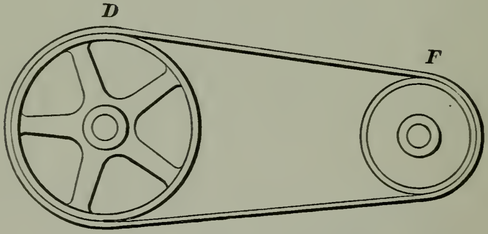


Fig. 62

At every revolution of the driver the belt is pulled through a distance equal to the circumference of the driver; in moving a distance equal to the circumference of the driven pulley, the belt turns the driven pulley one revolution. When two pulleys are connected by a belt their rim speeds are equal. Divide the distance the belt has moved by the circumference

of a pulley, and the quotient is the number of revolutions of the pulley: the revolutions of the pulleys are inversely proportional to their circumferences: that is, the smaller pulley revolves at the higher speed. This is precisely similar to the reasoning relative to gear speeds in Chapter VI.; the movement of the belt has the same relation to the speeds of two pulleys as the tooth transits have to the speeds of a pair of gears.

Speeds. As the ratio of the diameter to the circumference is always the same, the pulley speeds can be figured from the diameters of the pulleys without considering the belt speeds.

Let D = the diameter of the driver;
Let F = the diameter of the driven, or follower;
Let Rpm = the revolutions of the driver per minute;
Let rpm = the revolutions of the driven per minute;

rpm : Rpm : : D : F; that is, the speeds of the pulleys are inversely proportional to their diameters, the smaller pulley running at the higher speed.

Diameters. We figure by the diameters of pulleys the same as we do by the numbers of teeth in gears. From the proportion rpm : Rpm : : D : F, we have $D \times Rpm = F \times rpm$; that is, *The product of the diameter of the driver by the revolutions of the driver is equal to the product of the diameter of the driven by the revolutions of the driven.* If the driven pulley is to run twice as fast as the driver, then the diameter of the driver must be twice that of the driven. If the driven pulley is to run only a third the speed of the

driver, then the driver must be a third the diameter of the driven.

From $D \times Rpm = F \times rpm$ we have $D = \frac{F \times rpm}{Rpm}$, and $F = \frac{D \times Rpm}{rpm}$, which, when put into words, is the rule for the diameter of either pulley, when the diameter of the other pulley and the speeds of the two shafts are given: *Multiply the diameter of the given pulley by its revolutions per minute, and divide the product by the revolutions per minute of the required pulley, and the quotient is the diameter of the required pulley.*

Examples: A driving shaft runs 140 revolutions per minute; the driven pulley is 10″ in diameter, and is to run 350 revolutions per minute; what must be the diameter of the driving pulley? $\frac{10'' \times 350}{140} = 25''$, the diameter of the driving pulley.

The principal driving shaft is often called the "main line," and the smaller shafts driven by it are "counter-shafts."

The main line runs 160 Rpm; the counter-shaft pulley is 9″ in diameter and runs 320 rpm; what is the diameter of the pulley on the main line? $\frac{9'' \times 320}{160} = 18''$.

A pulley 24″ in diameter running 144 Rpm is to drive a shaft 192 rpm; what must be the diameter of the pulley on the driven shaft? $\frac{24'' \times 144}{192} = 18''$.

From $D \times Rpm = F \times rpm$ we have also the formulas for speeds, $Rpm = \frac{F \times rpm}{D}$ and $rpm = \frac{D \times Rpm}{F}$, which, when put in words, is the rule for the speed of either shaft, when the speed of the other shaft and

the diameter of the two pulleys are given: *Multiply the given speed by the diameter of the pulley that has that speed, divide the product by the diameter of the other pulley, and the quotient is the speed of the other pulley.*

Example: A 16′ fly wheel, running 70 Rpm drives a 7′ pulley; what is the speed of the pulley? $\frac{16 \times 70}{7} = 160$ rpm.

Jack Shafts. The first shaft belted off from a fly wheel is often called a "jack shaft." In Fig. 63, a jack shaft carries a pulley D; on a main line are the pulleys F and d; on another main line is the pulley f.

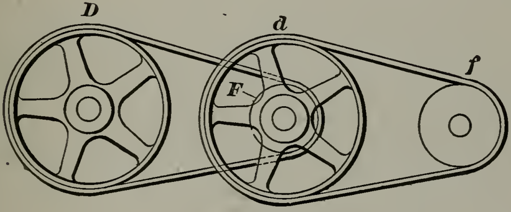


Fig. 63

The jack shaft runs 160 Rpm; D is 60″ diameter and drives F 140 rpm; what is the diameter of F? $\frac{60'' \times 160}{140} = 68\frac{4}{7}''$.

Although F figures $68\frac{4}{7}''$, yet in this case it is well to put on a 68″ pulley, because a belt "creeps," or slips, so that it does not usually drive a pulley quite so fast as our figuring might show.

The second main f is to run 186 rpm; what should be the diameter of f, the 72″ driver d running 140 Rpm? $\frac{72 \times 140}{186} = 54.19''$.

Here again we should let the driven pulley be smaller than it figures, and should put on a 54″, so as to be sure to keep up to speed.

Where one pulley drives another there are four quantities in relation, namely, the diameters of the two pulleys and their speeds. It will be noticed that by the foregoing rules we have to know three of these quantities, and then a rule tells us how to find the fourth. When one shaft drives another, which in turn drives a third shaft, as in Fig. 63, the figuring can be done step by step, from one shaft to the next, and so on to any number of shafts.

An examination of the figuring in connection with D and f, Fig. 63, will show that we arrive at the relative speed of f to D from the basis, $\text{Rpm} \times D \times d = \text{rpm} \times F \times f$; that is, *The continued product of the speed of the first driver and the diameters of all the drivers is equal to the continued product of the speed of the last driven by the diameters of all the driven pulleys.* In this combination of driving f by D, there are six quantities, any one of which can be found when we know the other five, by figuring from one shaft to the next step by step.

Selecting Diameters of Pulleys. It often happens that, while we know the speed of the shafts, we have only one pulley to start with, and have to decide upon the diameters of the three others; or

we may not have any pulley and have to decide upon all. In such cases we write down the ratio of the speed of the first driver to the speed of the last follower as being equal to the ratio of the product of the diameters of the driven pulleys to the product of the diameters of the drivers; thus $\frac{Rpm}{rpm} = \frac{F \times f}{D \times d}$. We can now select available diameters that, when multiplied together as indicated, will satisfy the ratio.

Example: A 4″ diameter pulley on an emery wheel spindle is to run 1400 rpm, the main line running 140 Rpm, and is to drive through a counter-shaft; what diameter of pulley can go on the main line and what can be the diameters of the two pulleys on the counter-shaft? In this example $\frac{Rpm}{rpm} = \frac{140}{1400} = \frac{1}{10}$; hence, $\frac{1}{10} = \frac{F \times f}{D \times d}$. Now as we are to have two drivers and two followers, it will be convenient to factor the ratio $\frac{1}{10}$, which can be done in a multitude of ways, but perhaps $\frac{1 \times 1}{2 \times 5}$ will be as convenient as any. We can now multiply one of the figures above the line by any number that will give us an available diameter for a driven pulley so long as we multiply one of the figures below the line by the same number for a driver. Multiplying both terms of ½ by 12 we obtain 12″ as the diameter of the driven pulley on the counter-shaft, and 24″ as the diameter of a driver. As the driven pulley on the wheel spindle is 4″ in diameter, we multiply both numerator and denominator of $\frac{1}{5}$ by 4 and obtain $\frac{4}{20}$; 20″ then can be the diameter of the other driver, which, so far as the speed of the emery wheel is concerned, can go on either the main line or the counter-shaft.

A pulley that is a follower can go on any shaft without affecting the speed of the last follower; we

should make sure, however, that in any arranging of pulleys we do not place a driver where a follower should go.

When two pulleys are connected by a belt, their diameters are generally figured as if their rim speeds were alike, but there are several things that affect the speed of a follower, so that it will not be exactly as figured.

Effect of Belt on Speeds. The creeping of a belt always causes the driven pulley to slow down. A belt must always have some thickness which makes the effective diameter of a pulley larger than the real diameter by an amount practically equal to a single thickness of the belt. This slows down a driven pulley that is smaller than the driver, and speeds up a driven pulley that is larger than the driver. Where a high speed is to be maintained the thickness of the belt must be allowed for in sizing the pulleys.

Example: A pulley 1″ in diameter is to run eight times as fast as its driver; what must be the diameter of the driver, the belt being ⅛″ thick? The effective diameter of the driven pulley is 1⅛″, which calls for 9″ as the effective diameter of the driver, or 8⅞″ real diameter. If the effective diameter of the driver cannot be larger than 8″, we can reduce the diameter of the driven pulley down to ⅞″.

The relative speeds of gears in a train are always exact, but pulleys are subject to variations.

Chapter VIII.

Change Gears in Screw Cutting.

Change gears in screw cutting are merely a case in gear speeds, Chapter VI., in which we know the revolutions of the driving shaft and of the following shaft, and it is required to figure gears that will connect the two shafts. The turns to one inch of the screw to be cut correspond to the revolutions of the driving shaft, and the turns of the lead screw to advance the carriage one inch correspond to the revolutions of the following shaft.

Lathe Gearing. In Figs. 64 and 65 the spindle S carries the screw to be threaded, and the lead screw L moves the carriage. In many lathes a change gear is not put directly upon the spindle, but upon the stud s, which is driven by the spindle through an intermediate gear i. If the two gears S and s are not alike, we can put equal gears on D and F, Fig. 64, and trace a thread upon a blank to learn what number of turns to one inch we can reckon the lead screw; or, we can refer to the screw cutting table and see what number of turns to an inch is cut with equal gears. This number is the number of turns to an inch that we reckon the lead screw to

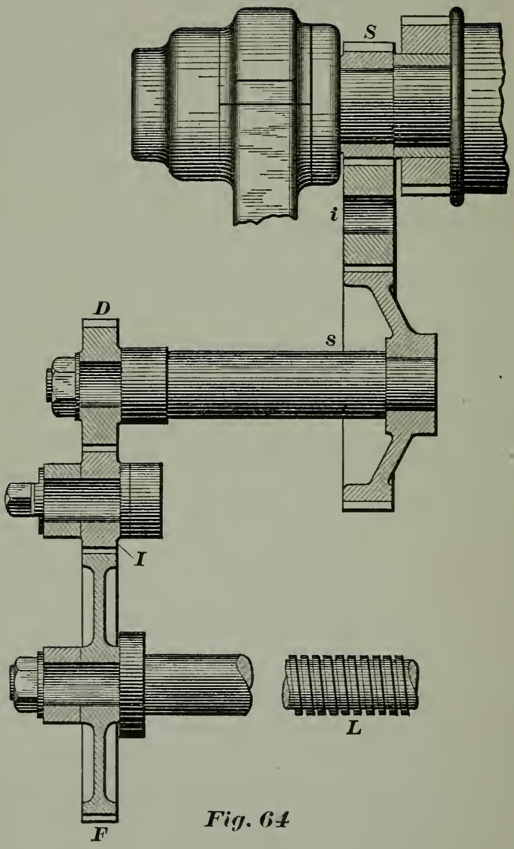


Fig. 64

have, no matter what its real number of turns to an inch is. Having learned this number, we pay no attention to the gears S and s.

Fig. 64 is simple-geared; Fig. 65 is compound-geared. In Fig. 64 the spindle gear D is a driving gear that drives F through the intermediate I. I is sometimes called the stud-gear. In Fig. 65, D is a driver, meshing into the stud-gear f, which is a follower; the other stud-gear d is another driver, which drives the follower F. F is upon the lead screw, and is commonly called the lead screw gear.

Let L = the number of turns to one inch that the lead screw reckons.

Let N = the number of turns to one inch of the screw to be threaded.

Let D = the number of teeth in the spindle gear.

Let F = the number of teeth in the lead screw gear.

Let d = the number of teeth in the driving gear on the stud.

Let f = the number of teeth in the following gear on the stud.

A screw-cutting lathe is geared according to the number of *turns* to an inch of the screw to be threaded, but the threading tool is selected according to the number of threads to an inch; that is, the gears correspond to the turns to an inch, but the tool corresponds to the pitch of the thread.

Simple Geared. Regarding the spindle S, Fig. 64, as a driving shaft and the lead screw as a follower, the product of the number of turns to an inch

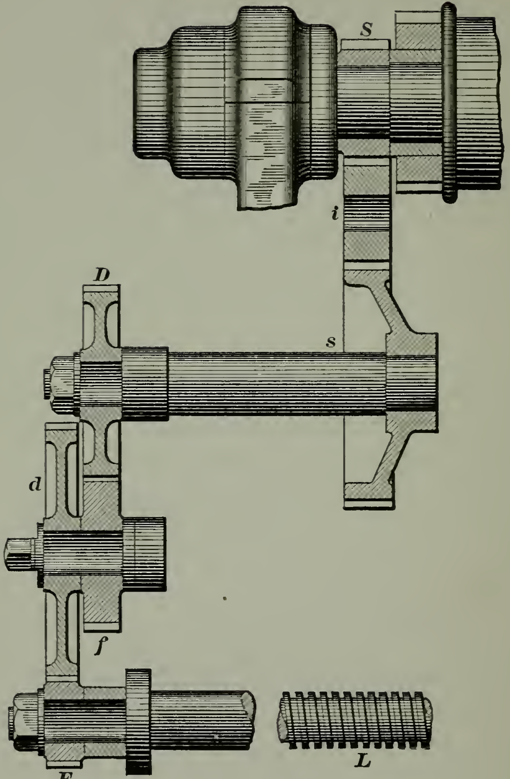


Fig. 65

to be threaded by the spindle gear is equal to the product of the turns to an inch of the lead screw by the lead screw gear. The formula for this is $ND = LF$.

This is only another way of saying that in a simple-geared lathe the tooth transits of the spindle gear and of the lead screw gear are equal, as in a pair of gears, Chapter VI.

Compound Geared. In a compound-geared lathe, Fig. 65, the continued product of the turns to an inch to be threaded and the driving gears, is equal to the continued product of the turns to an inch of the lead screw and the following gears. The formula for this is $NDd = LFf$. This formula and the one for simple gearing, in the foregoing paragraph, can be used to prove whether the right-gears have been selected. It is the same in principle as the formula for gear speeds, page 63; the revolutions of a driving shaft correspond to the turns to an inch of the thread to be cut, and the last follower corresponds to the lead screw.

Figuring Simple Gears. An easy way to figure simple-gearing is from the principle that the lead screw is to the screw to be threaded as the spindle gear is to the lead screw gear. That is, the ratio of the lead screw to the screw to be cut is equal to the ratio of the spindle gear to the lead screw gear. The formula for this is $\frac{L}{N} = \frac{D}{F}$, which means that the lead screw divided by the screw to be cut is equal to the spindle gear divided by the lead screw gear. Multiplying both terms of a ratio by the same number does

not change the value of the ratio. Hence we have the following rule for simple-gearing:

Write the number of turns to an inch of the lead screw above a line, and the number of turns to an inch of the screw to be threaded below the line, thus expressing the ratio in the form of a fraction, the lead screw being the numerator and screw to be threaded the denominator. Now find an equal fraction in terms that represent numbers of teeth in available gears. The numerator of this new fraction will be the spindle gear and the denominator the lead screw gear. The new fraction is usually found by multiplying the numerator and denominator of the first fraction by the same number.

Examples: A lead screw reckons 12 turns to an inch; a screw to be threaded 10 turns to an inch; required the gears. $\frac{12}{10}$ is the ratio of the spindle gear to the lead screw gear; we can multiply the terms of this ratio by any number that will give available gears. The change gears of many lathes have a common difference 7. Multiplying $\frac{12}{10}$ by $\frac{7}{7}$ we have $\frac{12 \times 7}{10 \times 7} = \frac{84}{70}$. This will give an 84 tooth gear for the spindle, and a 70 tooth gear for the lead screw.

To prove these gears, multiply the lead screw by its gear, $12 \times 70 = 840$; then the screw to be threaded by the spindle gear, $10 \times 84 = 840$; the two products being equal, the gears are correct.

A lead screw reckons 12: a screw is to be threaded $11\frac{1}{2}$; required the gears. $\frac{12}{11\frac{1}{2}}$ is the ratio; multiplying by $\frac{4}{4}$ we have $\frac{12 \times 4}{11\frac{1}{2} \times 4} = \frac{48}{46}$. 48 then, will do for the spindle, and 46 for the lead screw. Prove these gears as in the last example.

Example: It is required to thread a screw $\frac{7}{16}$ inch lead, in a lathe having a lead screw 8 turns to an inch; what gears can be used?

Dividing $1''$ by the lead, as in Chapter V., we obtain the turns to an inch: $1 \div \frac{7}{16} = \frac{16}{7}$, which means that $\frac{7}{16}$ inch lead is the same as $\frac{16}{7}$ turns to an inch or $2\frac{2}{7}$ turns to an inch.

Dividing the turns of the lead screw by the turns to be threaded, we have $8 \div \frac{16}{7} = \frac{56}{16}$.

Multiplying by $\frac{2}{2}$ in order to obtain available gears we have $\frac{56 \times 2}{16 \times 2} = \frac{112}{32}$.

A 112 gear will go on the spindle and a 32 on the screw.

Ratio in its Lowest Terms. It is often convenient to reduce the ratio to its lowest terms. Thus, in the last example, $\frac{56}{16} = \frac{7}{2}$. With the ratio in its lowest terms we can soon learn whether available gears are among those on hand. $\frac{7 \times 12}{2 \times 12} = \frac{84}{24}$. Again, $\frac{7 \times 14}{2 \times 14} = \frac{98}{28}$, and so on.

Assuming One Gear. We can assume one gear and from it figure the other gear.

Assuming the Lead Screw Gear. From $ND = LF$ we have $D = \frac{LF}{N}$, which means that we can assume the gear on the lead screw and figure the spindle gear by the following rule:

Multiply the turns to an inch of the lead screw by the number of teeth in the lead screw gear, and divide the product by the turns to an inch of the screw to be cut; the quotient is the number of teeth in the spindle gear.

Example: A lead screw is 3 turns to an inch ; the gear on the lead screw has 56 teeth ; what spindle gear will cut 2 turns to an inch? $3 \times 56 = 168$; $168 \div 2 = 84 =$ the number of teeth in the spindle gear.

Assuming the Spindle Gear. From $ND = LF$ we also have $F = \frac{ND}{L}$, which means that we can assume the spindle gear and figure the lead screw gear by the following rule:

Multiply the turns to an inch to be cut by the number of teeth in the spindle gear and divide the product by the number of turns to an inch of the lead screw; the quotient is the number of teeth in the lead screw gear.

Example: It is required to cut 2 turns to an inch with an 84 tooth gear on the spindle, in a lathe having a lead screw 3 turns to an inch ; what gear must go on the lead screw? Multiplying the screw to be cut by the spindle gear we have $2 \times 84 = 168$. Dividing the product by the lead screw we have $168 \div 3 = 56 =$ the number of teeth in the lead screw gear.

Not Always Convenient to Assume a Gear. The assuming of one gear and the figuring of the other is not always so convenient as the rule on page 78, because the gear that we figure sometimes comes fractional, and we have to assume another gear and figure again.

For example, let us assume a 77-tooth gear for the spindle to cut 8 turns to an inch in a lathe whose lead screw figures 12 to an inch ; what gear shall we put on the lead screw?

Multiplying the turns to be cut by the spindle gear and dividing the product by the turns to an inch of the lead screw, we have the number of teeth in the lead screw gear, $51\frac{1}{3}$. $8 \times \frac{77}{12} = 51\frac{1}{3}$.

A gear of $51\frac{1}{3}$ teeth is impracticable, and we must assume another spindle gear and figure again. But if we write the lead screw above the line and the screw to be threaded below, as on page 78, we have $\frac{12}{8} = \frac{3}{2} = 1\frac{1}{2}$, and any two gears will answer, in which the spindle gear is one and a half times the lead screw gear.

It is a good plan to figure a pair of gears in two ways, as a check. Some machinists like to check their figuring by measuring a fine trace of the intended screw, made upon the blank in the lathe, with the gears in place.

Gearing to Cut a Metric Screw. A metre is $39.37''$ in length; there are 1000 millimetres in one metre; how shall we gear to thread a screw 1 millimetre lead in a lathe having a 12-turns-to-inch lead screw? As there are 1000 millimetres in $39.37''$, we obtain the number of millimetres in one inch by dividing 1000 by 39.37. $1000 \div 39.37 = 25.40005+$. This is near enough to 25.4 millimetres in an inch for practical purposes. Proceeding as before we have $\frac{12}{25.4}$ as the ratio of the spindle gear to the lead screw gear. Multiplying by $\frac{5}{5}$ we have $\frac{12}{25.4} \times \frac{5}{5} = \frac{60}{127}$. Hence a 60-tooth gear will go on the spindle stud, and a 127-tooth on the lead screw. When threading a French metric screw with an English

lead screw, there must be a 127-tooth gear, which is called a "translating" gear. This must always be a follower, in any lathe in which the screw is driven from the spindle.

Mistaking the Lead for Turns to an Inch. When a screw is not far from one inch lead, mistakes have been made in not clearly distinguishing between the lead and the turns to an inch. Thus, $1\frac{1}{4}$ inch lead has been mistaken for $1\frac{1}{4}$ turns to an inch, but $1\frac{1}{4}$ inch lead equals $\frac{4}{5}$ turns to an inch; $\frac{3}{4}$ of a turn to an inch has been taken to be $\frac{3}{4}$ of an inch to one turn or $\frac{3}{4}$ inch lead, but $\frac{3}{4}$ of a turn to an inch equals $1\frac{1}{3}$ inches to one turn or $1\frac{1}{3}$ inch lead.

Examples: It is required to thread a screw $1\frac{1}{4}$ inch lead, in a lathe $\frac{2}{3}$ of a turn to an inch.

$1\frac{1}{4} = \frac{5}{4}$ inch lead; $1 \div \frac{5}{4} = \frac{4}{5} =$ the required turns to an inch.

$$\frac{2}{3} \div \frac{4}{5} = \frac{2 \times 5}{3 \times 4} = \frac{5}{6}.$$

$$\frac{5 \times 14}{6 \times 14} = \frac{70}{84}.$$

A 70-tooth gear goes on the spindle and an 84-tooth gear goes on the lead screw.

It is required to thread a screw $1\frac{1}{4}$ turns to an inch, in a lathe having a lead screw $\frac{2}{3}$ of a turn to an inch:

$$1\frac{1}{4} = \frac{5}{4} = \text{turns to an inch.}$$

$$\frac{2}{3} \div \frac{5}{4} = \frac{2 \times 4}{3 \times 5} = \frac{8}{15}.$$

$$\frac{8 \times 7}{15 \times 7} = \frac{56}{105}.$$

A 56-tooth gear goes on the spindle and a 105-tooth gear goes on the lead screw.

It is required to thread a screw $\frac{3}{4}$ of a turn to an inch in a lathe $\frac{2}{3}$ of a turn to an inch.

$$\tfrac{2}{3} \div \tfrac{3}{4} = \frac{2 \times 4}{3 \times 3} = \frac{8}{9}.$$

$$\frac{8 \times 7}{9 \times 7} = \frac{56}{63}.$$

A 56-tooth gear goes on the spindle and a 63-tooth gear goes on the lead screw.

It is required to thread a screw $\frac{3}{4}$ of an inch to one turn in a lathe $\frac{2}{3}$ of a turn to an inch. $\frac{3}{4}$ of an inch to one turn is the same as $\frac{3}{4}$ inch lead.

$$1 \div \frac{3}{4} = \frac{4}{3} = \text{the required turns to an inch.}$$

$$\tfrac{2}{3} \div \frac{4}{3} = \tfrac{1}{2}.$$

$$\frac{1 \times 42}{2 \times 42} = \frac{42}{84}.$$

A 42-tooth gear goes on the spindle and an 84-tooth gear goes on the lead screw.

Before beginning to thread a screw the workman should be sure that he knows what the lead is to be, and whether right-handed or left-handed.

It is sometimes convenient to remember that if the thread to be cut is coarser, or has fewer turns to an inch than the lead screw, the larger gear will go on the spindle.

Fractional Thread. When a thread is not an exact whole number of turns to an inch it is called a fractional thread. In figuring the gears for a fractional thread, the terms of the ratio will sometimes be large enough for the numbers of teeth in available gears.

Example of Ratio with Large Terms. A thread $8\frac{1}{5}$ turns to an inch is to be cut in a lathe having a

lead screw 12 turns to an inch; $8\frac{1}{5}=\frac{41}{5}$ turns to an inch. Dividing the lead screw by the screw to be cut we have $12 \div \frac{41}{5}=\frac{12\times 5}{41}=\frac{60}{41}$, which can be the numbers of the teeth in the gears; 60 going on the spindle, and 41 on the lead screw.

Figuring Compound Gears. For compound gearing we have the rule:

Write the turns to an inch of the lead screw as a numerator of a fraction, and the turns to be threaded as a denominator.

Factor this fraction into an equal compound fraction.

Change the terms of this compound fraction, either by multiplying or dividing, into another equal compound fraction whose terms represent numbers of teeth in available gears.

The formula for compound gearing is $\frac{L}{N}=\frac{Dd}{Ff}$.

Example: A lead screw is $1\frac{1}{2}''$ lead, or $\frac{2}{3}$ turns to an inch; it is required to thread a screw $3\frac{1}{4}''$ lead or $\frac{4}{13}$ turns to an inch; what gears can be used?

$\frac{2}{3} \div \frac{4}{13}=\frac{2\times 13}{3\times 4}=\frac{2\times 13}{1\times 12}$.

Multiplying $\frac{2\times 13}{1\times 12}$ by $\frac{5}{5}$, we obtain two available gears, thus $\frac{2\times 13}{1\times 12}\times\frac{5}{5}=\frac{2\times 65}{1\times 60}$.

Multiplying by $\frac{24}{24}$ we obtain two more available gears; thus $\frac{2\times 65}{1\times 60}\times\frac{24}{24}=\frac{48\times 65}{24\times 60}$.

Gears 48 and 65 will be the two drivers D and d, Fig. 65, and 24 and 60 will be the two followers F and f.

To prove these gears, take the continued product of the lead screw and the followers, and see whether

it is equal to the continued product of the screw to be threaded and the drivers. $\frac{2}{3} \times 24 \times 60 = 960$. $\frac{4}{13} \times 48 \times 65 = 960$.

Assuming all the Gears but one. In compound gearing, we can assume all the gears but one, and then figure that one upon the principle given on page 77. The fundamental formula for four gears is $NDd = LFf$; and the formula for one of the drivers is $D = \frac{LFf}{Nd}$, from which we have the rule:

Assume the two following gears and one driver; divide the continued product of the lead screw and the two followers by the product of the screw to be threaded and the assumed driver; the quotient will be the other driver.

Example: What compound gears will cut 16 turns to an inch in a lathe 3 turns to an inch?

Let us assume 70 and 112 for the followers.

Assume 35 for one of the drivers.

$\frac{3 \times 70 \times 112}{16 \times 35} = 42.$

42 is the other driver which can go on at D, Fig. 65.

70 can go on the stud at f as a follower.

35 can go on the stud at d as another driver.

112 can go on the lead screw as a follower.

From $NDd = LFf$ we have the formula for one of the followers, $F = \frac{NDd}{Lf}$, from which we have the rule:

Assume the two drivers and one of the followers, divide the continued product of the turns to be cut and the two drivers by the product of the lead screw and one of the followers; the quotient will be the other follower.

Example: What compound gears will cut a screw of half millimetre lead in a lathe with a lead screw 3 turns to an inch?

½ $^m\!/\!_m$ lead = 2 turns to 1 $^m\!/\!_m$ or 50.8 turns to 1″.

Let us assume 28 and 30 as the two drivers.

One of the followers must have 127 teeth as shown on page 81. $\frac{50.8 \times 28 \times 30}{3 \times 127} = 112 =$ the other follower.

When Compound Gears are Available. When we wish to cut a screw that has either a too long or a too short lead to be reached with simple gearing, we have recourse to compound gearing, which is also available for a fractional lead when the terms of the fraction are large.

Example: It is required to thread a screw enough longer than ⅛ inch lead to gain .005 inch in 96 turns, with a lead screw 12 turns to an inch; what gears shall we use?

⅛ inch lead will advance 12 inches in 96 turns; hence 96 turns of the required lead = 12.005″ and $\frac{96}{12.005}$ = the required turns to an inch.

$\frac{96}{12.005} = \frac{96000}{12005}$ which reduces to $\frac{19200}{2401}$ which is also the required turns to an inch.

The lead screw $12 \div \frac{19200}{2401} = \frac{12 \times 2401}{19200} = \frac{2401}{1600} = \frac{49 \times 49}{40 \times 40}$ which are compound gears that might be available, though a pair larger than one of the $\frac{49}{40}$ would be needed in most lathes.

Multiplying $\frac{49}{40}$ by $\frac{2}{2}$ we have $\frac{98}{80}$ and our two drivers are 98 and 49, while the two followers are 80 and 40.

Either driver can go on the spindle, as is found the more convenient. Either follower can go on the lead screw.

Approximate Ratios. When the terms of a ratio are large and cannot be factored, we can generally either add to the terms or subtract from them, and thus obtain an approximate ratio in terms that have available factors.

Example: It is required to thread a screw 144 turns in 12.022 inches, in a lathe that figures 12 turns to an inch. Dividing 144 by the number of inches advanced in the 144 turns, we have $\frac{144}{12.022} = \frac{144000}{12022}$ = the required turns to an inch. Dividing the turns of the lead screw by the turns to be cut, as in previous examples, we have: $12 \div \frac{144000}{12022} = 12 \times \frac{12022}{144000} = \frac{12022}{12000} = \frac{6011}{6000}$ = the ratio of the driving gears to the driven.

The term 6011 is prime, but as the terms are quite large, and the ratio is not far from 1, we can add a small number to each of the terms, or we can subtract a small number from each term without materially changing the ratio. If we add the same number to both terms the ratio will be smaller; if we subtract the same number, the ratio will be larger.

We can add or subtract, according to which variation is the less objectionable. A slight lengthening of the lead is generally less objectionable than shortening, therefore, first subtract 1 from both terms; we find in the resulting ratio $\frac{6010}{5999}$, that 5999 has 857 as one of its prime factors, which is too large for a change gear. We try more subtractions until we come to subtracting 5, leaving a ratio $\frac{6006}{5995}$, which can be factored into $\frac{66 \times 91}{55 \times 109}$.

If these gears will not go into place and run together we can select other terms for our required ratio.

The principle of changing the terms of a ratio is, if each term of a ratio be increased, or if each term be decreased by a like part of itself, the value of the ratio will not be changed. When a ratio is in its lowest terms they cannot be either increased or decreased proportionally, by fractional parts of themselves, and have whole numbers for the new terms. As the teeth of the change gears must be in whole numbers, our only recourse is to select the nearest ratio that can be expressed in whole numbers.

Proving the Gears. The movement of the tool carriage to one turn of the spindle, is equal to the lead of the lead screw multiplied by the ratio of the driving gears to the driven gears. For the gears we have just figured the ratio is $\frac{6006}{5995}$. The lead of the lead screw being $\frac{1}{12}$ inch we have $\frac{1\times6006}{12\times5995}$ inches movement of the carriage to every turn of the spindle. In the 144 turns we have $\frac{144\times6006}{12\times5995}=12.02202$ which is near enough to 12.022 for practical purposes.

Vulgar Fractions Sometimes Convenient. It is often more convenient to express the turns to an inch with a vulgar fraction than to reduce the turns to a whole number and a long decimal. A vulgar fraction may be exact, while the decimal expression can be only approximate. Thus, in the last example the turns to an inch were $\frac{144000}{12022}$, and the ratio for the gears is exactly $\frac{6011}{6000}$, while the turns to an inch expressed decimally are 11.97804+, which is not so convenient, as it is rather a long operation to divide

the turns to an inch of the lead screw 12 by 11.97804.

In factoring the terms of a ratio, a table of prime factors is a great convenience.

Other Ratios. If a ratio is very near ½, we can add 1 to the upper term or numerator, and 2 to the lower term or denominator; or, we can subtract 1 from the numerator and 2 from the denominator, until terms are reached that are not prime; if the ratio is near ⅔ we can change the upper term by 2 and the lower by 3, and so on.

Example: It is required to thread a screw 24 turns in 3.001 inches, in a lathe whose lead screw figures 6 turns to an inch. Dividing the turns by the number of inches advanced, as before, we have $\frac{24}{3.001} = \frac{24000}{3001}$ as the number of the required turns to an inch; $6 \div \frac{24000}{3001} = \frac{6 \times 3001}{24000} = \frac{3001}{4000} =$ ratio of driving gears to the driven.

As 3001 is prime, we must resort to either additions or to subtractions. The fraction $\frac{3001}{4000}$ is so near ¾ that we can add 3 to the numerator and 4 to the denominator, without materially changing the value of the ratio or fraction; or we can subtract 3 from the numerator and 4 from the denominator. In this case the additions decrease the value of the ratio, while the subtractions increase it.

Let us first try additions; after three additions or trials, we find that $\frac{3010}{4012}$ can be factored into $\frac{70 \times 43}{68 \times 59}$.

Proving these gears, as before, we have 24 turns of our screw in 3.00099 inches, which is probably near enough to 3.001, though a little too short.

We can subtract from the terms of our ratio $\frac{3001}{4000}$ and obtain gears that will lengthen the lead.

Thus, $\frac{3001-12}{4000-16}=\frac{2989}{3984}$ which can be factored into $\frac{49\times61}{48\times83}$. With these gears we shall have 24 turns of our screw in 3.001004 inches.

When one of the terms is much greater than 10000 it may be impracticable to figure gears that can be used on account of there not being room enough to get them into place. If a term is inconveniently large, the ratio can generally be approximately expressed in smaller terms by means of continued fractions. A short treatment of continued fractions is to be found in the "Practical Treatise on Gearing."

In cutting a long screw, the carriage is usually run back by hand, but in a fractional lead it may be necessary to run back by power, because the nut cannot be shifted to any place where the thread tool will match the thread groove.

Figuring the Turns to an Inch. It is an interesting problem to figure the turns to an inch that can be threaded with a given number of change gears. Some makers of lathes send out a table of the turns that can be threaded with the gears furnished, when simple geared. A common system of change gears runs from 28 teeth to 112 inclusive, varying by 7, with an extra 56-tooth gear, making 14 gears in all. In this system there are 157 different combinations of simple-gearing, but among these there are 40 duplicate ratios, leaving only 117 different turns to an inch that can be threaded. If a system of

change gears differ by 8, or by any even number, there is a still greater proportion of duplicate ratios, and, in consequence, fewer different turns to an inch can be threaded with this system.

From the principle on page 77, the rule for figuring the turns to an inch is easily derived. From the formula $ND = LF$ we have $N = \frac{LF}{D}$, which means that we can figure the turns to an inch that any two gears will thread, by the following rule:

Multiply the turns to an inch of the lead screw by the number of teeth in the lead screw gear and divide the product by the number of teeth in the spindle gear; the quotient is the number of turns to an inch that the gears will thread.

Example: In a lathe whose lead screw is 12 turns to an inch, what will be cut with a 35-tooth gear on the spindle and a 91-tooth on the lead screw?

$\frac{12 \times 91}{35} = 31\frac{1}{5}$ turns to an inch.

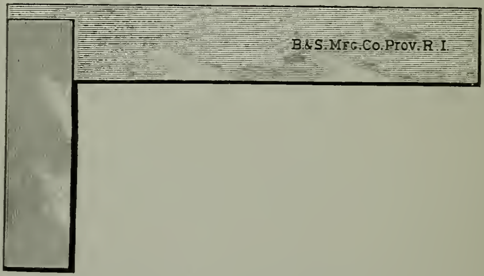
Turns to an Inch with Compound Gearing. From the formula $NDd = LFf$, on page 77, we have $N = \frac{LFf}{Dd}$ and the rule:

Divide the continued product of the lead screw and the two followers by the product of the two drivers; the quotient is the number of turns to an inch that the gears will thread.

Example: In a lathe whose lead screw is 12 turns to an inch, how many turns to an inch will be threaded with a 42 gear on the spindle meshing into an 84 on the stud, and a 77-tooth on the stud driving a 112 on the lead screw? $\frac{12 \times 112 \times 84}{42 \times 77} = 34\frac{10}{11}$.

It might take some time to figure out a table of all the turns to an inch that can be threaded with compound gearing using 4 gears at a time and having 14 gears to select from. According to the law of combinations we can form 1001 different combinations 4 in each, with 14 different things to select from. In the case of compound gearing we can obtain 6 different ratios with every combination of 4 gears; hence, with 14 gears to select from, it is possible to obtain 6006 different ratios. In an ordinary system of change gears, there would be duplicate ratios. If the duplicates are about in the proportion of those in simple gearing there are about 4500 different ratios to be obtained from the 14 gears.

With 20 gears to select from, 4 in a combination, it is possible to obtain more than 21,000 ratios.



Chapter IX.

Angles. Setting a Protractor. Working to an Angle.

Working to an Angle is one of the most perplexing things that ever perplex an apprentice, and many journeymen as well. There may be a mistake as to the size of an angle on account of not knowing where it begins or ends. The measuring of an angle may be wrong because the measuring instrument or protractor indicates one angle when another is wanted. Working to an angle with a machine may develop the disturbing surprise that the workman has chosen a wrong setting for the machine, because he either did not understand from what line the figuring of the angle was begun, or because the machine indicates an angle different from the one that is wanted.

It requires careful study to learn how to work to an angle, and an apprentice cannot expect this to be an easy task.

An Angle, as commonly defined, is the space between two straight lines that meet in a common point. Another definition is that an angle is the difference in direction between two lines that either meet or would meet if sufficiently prolonged. In

Fig. 66, the difference in direction between the lines AO and BO is the angle AOB. AO and BO are the *sides*, and O is the *vertex* of the angle.

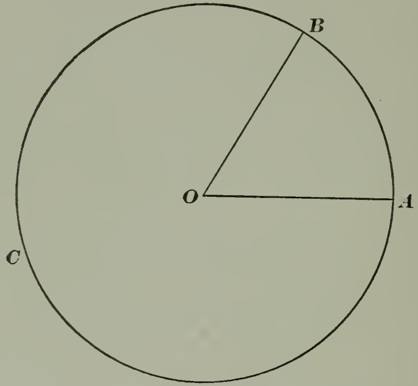


Fig. 66

The circumference of a circle drawn about the vertex as a centre, and through the sides of an angle, can be used to measure the angle. Thus, the circumference ABC is drawn about the vertex O, and the angle AOB is measured with the arc AB.

In order to measure angles, the circumference is divided into 360 parts; one of these parts is called a *degree*. A degree is divided into 60 parts called *minutes;* and a minute is divided into 60 parts called *seconds*.

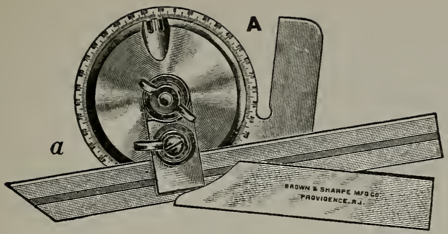


Fig. 67

One form of instrument for measuring angles, called a *protractor*, is seen in Fig. 67. At Aa is a circle divided into degrees. The length of one degree, on an arc of 1 inch radius, is .01745 inch.

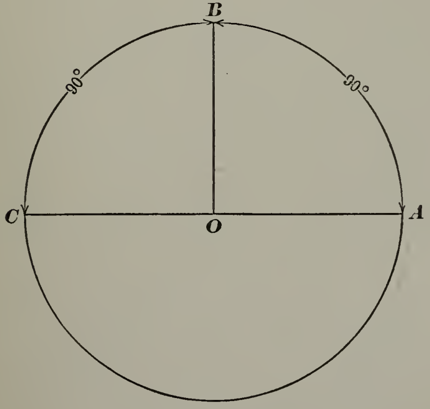


Fig. 68

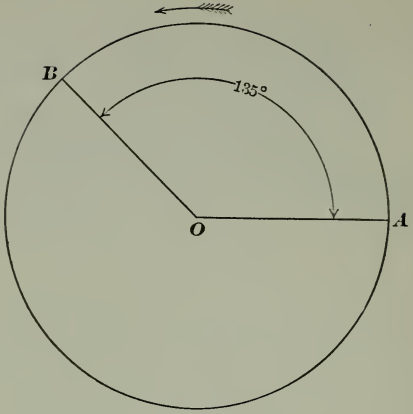


Fig. 69

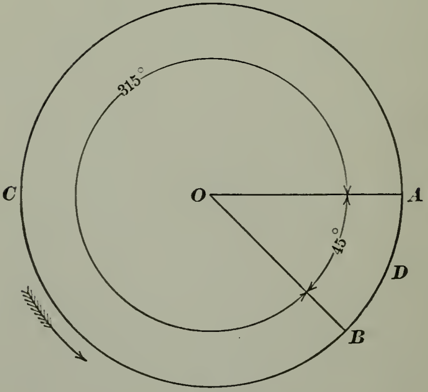


Fig. 70

A Right Angle is measured with a quarter of the circumference of a circle, which is equal to 90°. In Fig. 68, AOB and BOC are right angles. A line BO is at right angles with a straight line AC, when the angles on each side of BO are equal.

A try-square is a familiar example of a right angle.

The half circumference ABC, which equals 180°, measures two right angles, but as the side AO of one right angle and the side CO of the other right angle form one and the same straight line AOC, 180° is not usually regarded as an angle, in machine work.

Different Angles and their Uses. Two uses of angles are common in machine making, one to measure a circular movement, the other to measure a difference in direction. Angles can be studied from different points of view, according to the use that is to be made of them. In general they might be regarded as being formed with a radius OB, Figs. 69 and 70, moving about O, the origin of angles being at A. For some uses the radius OB is moved in the direction of the arrows, contrary to the hands of a clock. The radius, as shown in Fig. 69, has reached B, and formed an angle, AOB, of 135°; and in Fig. 70, the radius has passed C and reached B, the arc ACB being 315°.

An angle can be measured in two directions: thus, in Fig. 70, the angle AOB can be measured with the arc ACB, which is 315°, and AOB can

also be measured with the arc ADB which is only 45°.

The difference in direction between two lines is the same, no matter in which way it is measured. Subtract what an angle measures in one way from 360°, and the remainder is what it measures in the other way. Thus, AOB is 315° measured with the arc ACB; subtracting 315° from 360°, the remainder, 45°, is the angle AOB when measured with the arc ADB. Either way of measuring indicates the mere difference in direction; but, in working to an angle, the way that is wanted must be clearly understood.

When angles are used to measure rotation, if a piece has rotated through a certain angle, it is not always convenient to use the other angle to express the rotation. Thus in Fig. 70, 315° expresses the *movement* of OB through C around to B, while it might be said that the *direction* of OB is 45° from OA. The radius OB can continue to rotate through any number of degrees; and when it has rotated through 360° it again coincides with the radius OA; the two radii again coincide at 720°, at 1080°, and so on. The rotation of a shaft can be expressed in degrees; 90° are equal to a quarter of a revolution, 360° to one revolution, 720° to two revolutions.

The consideration that one angle is the difference between 360° and another angle seldom comes up in machine making, but is not uncommon to have an association of two angles that together equal 180°

The Supplement of an Angle. In Fig. 71, the straight line BO meets the straight line AD at O, and the angle AOB added to BOD equals 180°. Subtract one angle from 180° and the remainder is equal to the other angle. The difference between

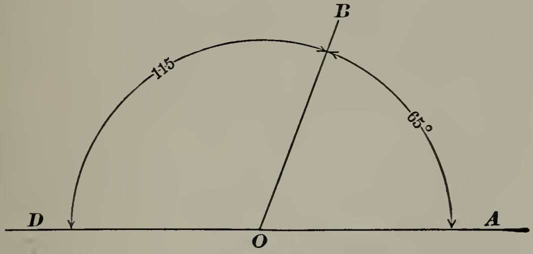


Fig. 71

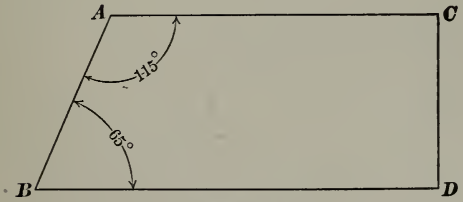


Fig. 72

180° and any angle is called the *supplement* of the angle. When the sum of two angles equals 180°, each angle is the supplement of the other.

An *acute* angle is less than 90°, as AOB. An *obtuse* angle is greater than 90°, as BOD.

The association of two angles whose sum is equal to 180° is also shown in Fig. 72. If the piece ABCD has the side AC parallel to the side BD, the sum of the angles CAB and ABD will be equal to 180°, and if the side AB inclines so as to make the angle ABD acute, the angle BAC will be obtuse. The angle BAC is 115°, which subtracted from 180° leaves 65° as the angle ABD; and, as the sides AC and BD are parallel, the sum of these two angles equals 180°.

From the foregoing it will be seen that:

When two angles, in the same plane, are associated, and their sum is equal to 180°, one side of each angle is upon one and the same straight line, while the other sides may be either upon the same line, as BO, Fig. 71, or upon two parallel lines, as AC and BD, Fig. 72.

It is important to understand Figs. 71 and 72. Unless the relation of an angle to its supplement is clearly understood, it is well-nigh useless to attempt to do anything with angles.

Angles Associated with 90°. Two angles may be associated with 90°. Sometimes the sum of the angles equals 90°; at other times it is the difference between the two angles that is equal to 90°. A drawing may call for one angle and the machine have to be set to the other. This association of two angles with 90° leads to more mistakes than all other things connected with angles.

It is utterly useless for one to attempt to work in angles until one can easily untangle any complication with 90°.

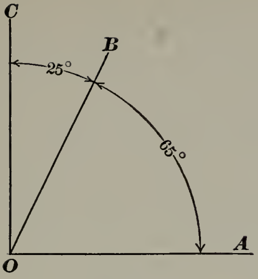


Fig. 73

Complement of an Angle. The angle AOC, Fig. 73, is a right angle, and the sum of the angles AOB and BOC is equal to a right angle. The difference between any angle and a right angle is called the *complement* of that angle. Thus, in Fig. 73, 25° is the difference between 65° and 90°, and 25° is the complement of 65°. If two angles are equal to 90°,

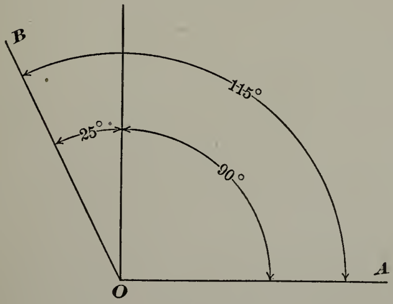


Fig. 74

each angle is the complement of the other; 65° is the complement of 25°.

In Fig. 74, the angle AOB is greater than a right angle, being 115°, or equal to 25° added to 90°.

Setting a Protractor to an Angle Less than 90°. Another form of protractor is shown in Fig. 75; a part of a circle being graduated around E. The

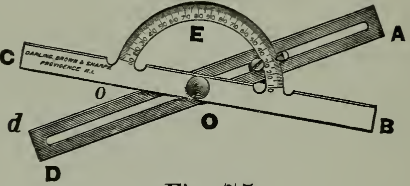


Fig. 75

angle AOB is indicated by the pointer, which is now at 30°. By a principle of geometry, the angle COD is equal to AOB. In this style of protractor, the figuring runs from 10° on each side to 90° at the middle. When the pointer is at 90° the blade AD is at right angles with the beam BC. A large part of the angles, measured with a protractor, are less than 90°, so that this style of figuring answers for a direct reading of many of the angles that come up in practice. In a direct reading, that is, when the figures indicate the angle required, the figures are opposite the angle that is to be used. Thus, in Fig. 75, if

the required angle is 30°, the figures indicate a setting of 30°, and the angle that is used is opposite, at Cod, which is also 30°.

For angles less than 90°, the side of the beam BC is the zero line, and the blade measures the angle from that line.

Setting the Protractor for an Angle Greater than 90°. When the required angle is greater than 90°, the figures on the protractor do not directly indicate the number of degrees in the angle. The sum of the two angles AOB and BOD equals 180°, the principle being the same as in Fig. 71, the same letters referring to similar lines. Hence,—

The angle greater than 90° is upon the same side of the blade AD as the figuring is, and upon the opposite side of the beam BC.

Example: It is required to set the protractor to 150°. As 150° is greater than 90°, subtract 150° from 180°, and the remainder 30° is the setting. The pointer is now at 30° and the angle BOD is 150°.

Uses of a Protractor. A few of the uses of the protractor, Fig. 67, are illustrated in Fig. 76. An angle less than 90° can be read directly from the figures on the protractor, when the work is placed between the beam and the blade as in B, E, H, L, M, and P. In N and O, also, the angle of the work is indicated by the figures. When the protractor is set to 90°, the blade and beam are at right angles to each other, as in D. In each of the diagrams F,

G, I, J, K, the protractor is really measuring an angle greater than 90°, the angle being the difference between the figured setting of the protractor and 180°, as in the previous example.

Sometimes an angle of a bevel gear blank is conveniently measured from the end of the hub, as in diagram B, and at other times from across the other side of the blank, as in diagram J. In B, the protractor is set to 60°, and it is measuring 60°, but in F, though the protractor is set to 60°, it is really measuring 120°, which is the supplement of 60°. The angle of a bevel gear blank is usually figured from a line perpendicular to the axis, and the figures are for the side of the smaller angle; thus, for diagram F, a drawing would be figured 60° as if measured from the other side. It may, however, be more convenient to measure from the side shown in the diagram, and the protractor will measure correctly when set to 60°, but it is well to remember that the protractor in F is really measuring 120°. In Fig. 72, a drawing would call for the angle ABD to be 65° and would not figure the 115° at all, but if the protractor, Fig. 75, were set to 65° the obtuse angle of the protractor would be 115° and would fit the angle BAC.

In order to use a protractor understandingly it will be seen that the zero line must be known; and it may be asked, "Why not figure a protractor with more than one series of figures, beginning from different zeros, so that a series can always be selected

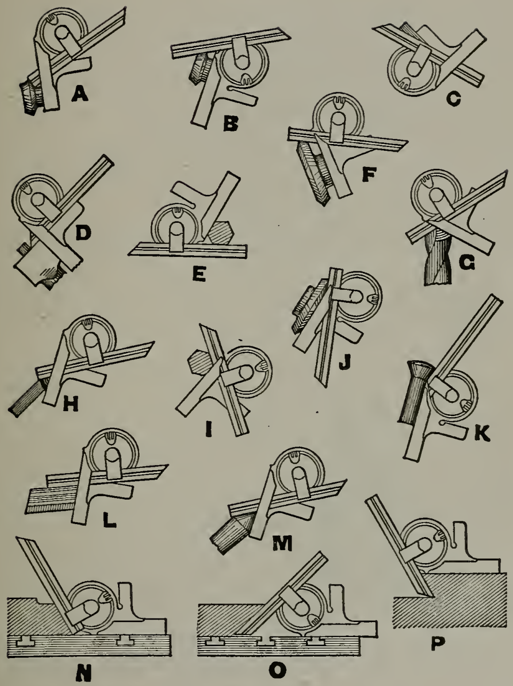


Fig. 76

that will read the angle correctly?" One reason is that, in whatever way a protractor is figured, there must be some mental calculation before beginning to set it.

In the diagrams A and C, Fig. 76, the zero line is indicated with the graduated line that is figured 90°: hence, subtract the setting of the protractor from 90° and the remainder is the angle of the piece being measured. Thus, at C, the reading of the protractor is 73°, which subtracted from 90° leaves 17° as the angle of the piece being measured.

Working to an Angle. The principle of setting a machine to work to an angle is similar to the setting of a protractor; the direction of the zero line must be known.

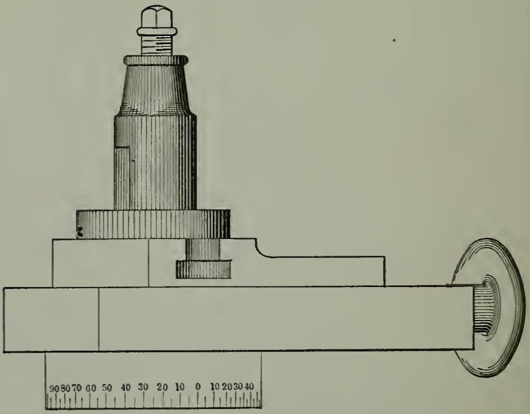


Fig. 77

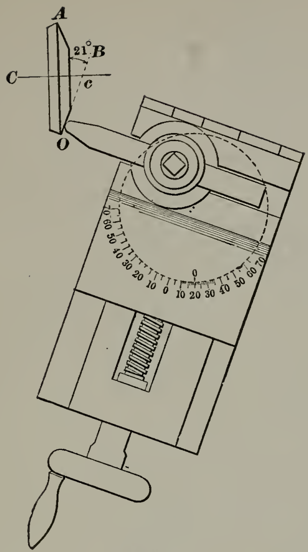


Fig. 78

In a Lathe. Angular work is often turned with a tool held in a compound rest, Fig. 77. Figs. 78 and 79 illustrate a compound rest. The zero line of a compound rest is at right angles to the centre line, Cc, of the lathe, the zero line being parallel to AO. The flat side of a plate, or disk, can be faced off with the compound rest set at zero.

Angles of Bevel Gear Blanks are usually figured from a plane perpendicular to the axis; thus, in Figs. 78 and 79, the angles are figured from AO, which is

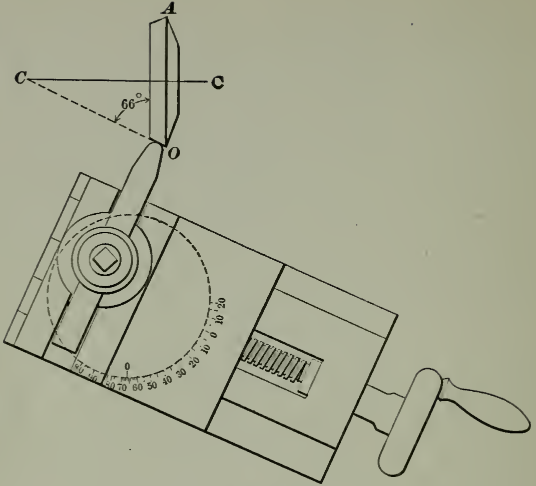


Fig. 79

perpendicular to the axis Cc. In turning to angles figured in this way the setting of the compound rest is just like the figures on the drawing; thus, in Fig. 78, the drawing calls for 21° in the angle AOB, and the rest is set to 21°. In Fig. 79 the angle AOC is 66° and the rest is at 66°. There may, however, be a technical reason for figuring the angles of a bevel gear blank from the axis Cc; in fact, a draughtsman that has never worked in a machine shop will naturally figure them from the axis. In Fig. 78 the tool is turning to the angle CcO, with the axis which is the complement of 21°.

To turn to an angle figured from the axis, the compound rest must be set to the complement of the angle. Thus, if the angle CcO, 69°, is called for, subtract 69° from 90°, and the remainder, 21°, is the setting for the compound rest.

It is better to figure the angles of a bevel gear blank from a line perpendicular to the axis, as in Figs. 78 and 79, to correspond to the figuring of a compound rest; the angles are also more easily measured from a line perpendicular to the axis than from a line parallel to the axis.

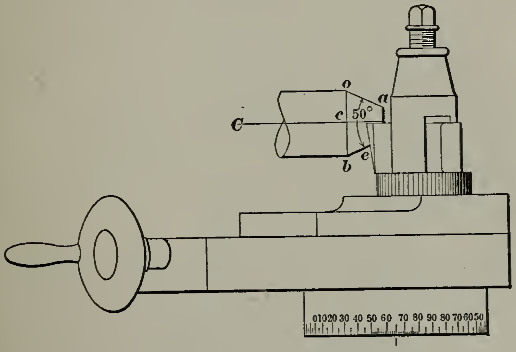


Fig. 80

Drawings Figured neither from the Centre Line nor from a Perpendicular to the Centre Line. In Fig. 80 a beveled or tapering piece is to be turned in which the side ao is 50° with the side eb. In order to set the compound rest the angle boa

must be known. By a law of geometry boa is the complement of the angle that oa makes with the centre line Cc. The beveled part being symmetrical with the centre line, the angle of oa with Cc is a half of the whole angle 50°, or 25°; and 25° subtracted from 90° leaves 65° as the setting of the compound rest. Most draughtsmen would figure a drawing of the piece in K, Fig. 76, in the same way as Fig. 80.

A Planer Head is figured to read zero when the tool slide is vertical, as in Fig. 81. In other words, when the slide is set to zero, and the vertical feed is in, the tool will plane straight up and down, or at right angles to the top of the table. If a drawing shows an angle measured from a vertical line, as in Fig. 82, the tool slide is set to the degrees called for on the drawing. The side AO is parallel to BC, and the piece is fastened so that BC either rests upon or is parallel to the top of the table. The angle of the side OB with the vertical line OD is not easily measured with a protractor, because the vertical line is not available to measure from. It is very seldom that a planed angle can be measured with the protractor set to the same number of degrees as the planer tool slide was set when the piece was planed. When an angle is measured from a vertical surface of the piece to be planed, a protractor will measure the angle when set as the planer tool-slide would be set in order to plane the angle; but it is not often that an angle is measured from a vertical surface. A

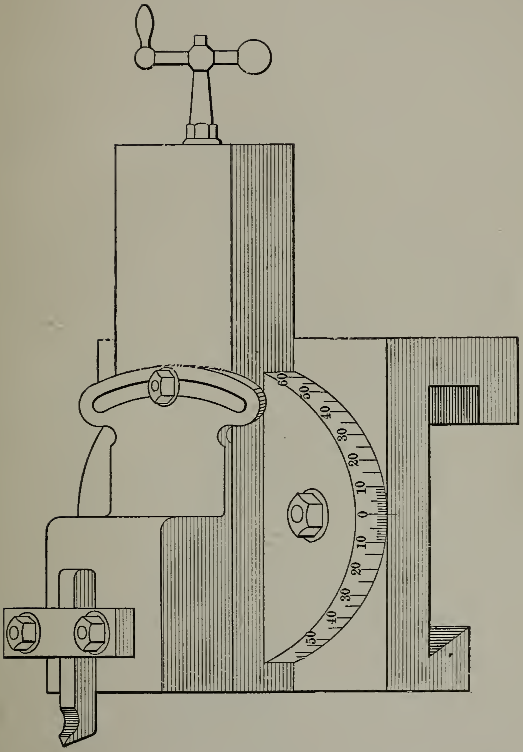


Fig. 81

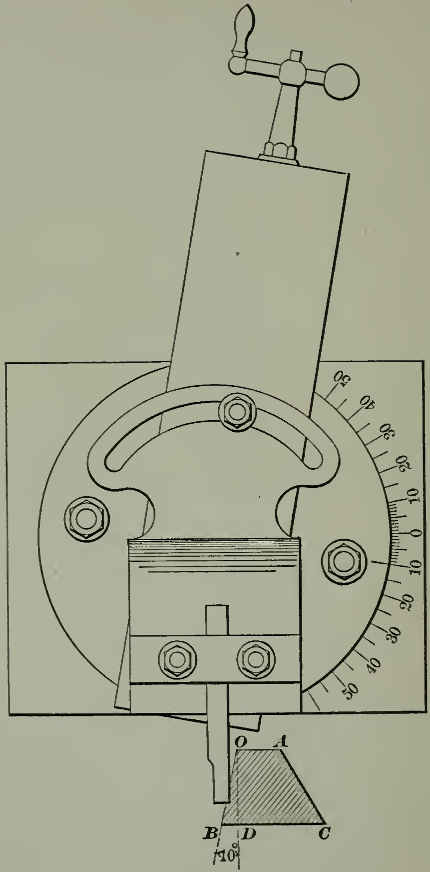


Fig. 82

vertical surface corresponds to the vertical line OD, Fig. 82.

The angle AOB, Fig. 82, is the sum of BOD added to the right angle AOD, which is equal to $10° + 90° = 100°$. Subtract 100° from 180° and the remainder is 80° which is the setting of the protractor. The protractor, Fig. 83, is set at 80° and is measuring the angle AOB, which is 100°. The angle OBC is equal to the remainder after subtracting the angle BOD from the right angle ODC; $90° - 10° = 80°$, which is the angle OBC.

In Fig. 84, a protractor is measuring the angle OBC. If preferred, the angle OBC can be regarded as the remainder after subtracting AOB from 180°; $180° - 100° = 80°$ as in Fig. 72.

Angle Measured from the Table, or from a Horizontal Line. In order to plane an angle that is measured from a horizontal line, when the angle is less than 90°, the angle is subtracted from 90°; the remainder being the setting of the tool slide. Thus, in Fig. 85, the angle ACB is 60°, which being subtracted from 90° leaves 30° as the setting of the tool-slide. The principle of the foregoing is shown in Fig. 73.

To plane to an angle greater than 90° from a horizontal line, subtract 90° from the angle and the remainder will be the setting of the tool-slide. Thus, to plane to an angle of 115° from the horizontal, subtract 90° from 115° and the remainder 25° is the setting for the tool-slide. See Fig. 74.

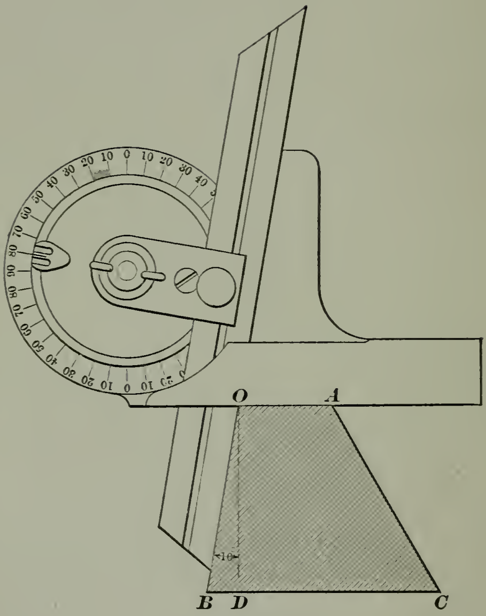


Fig. 83

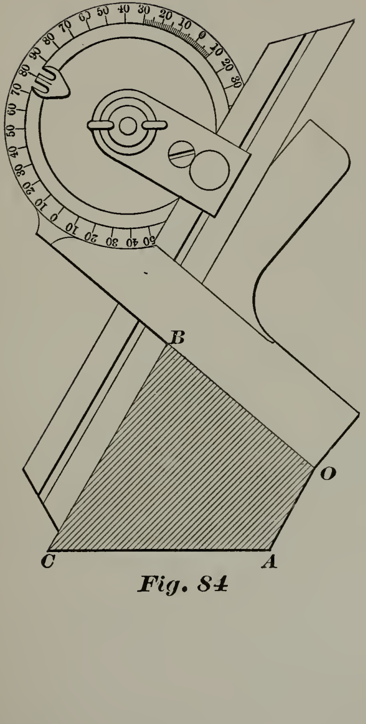


Fig. 84

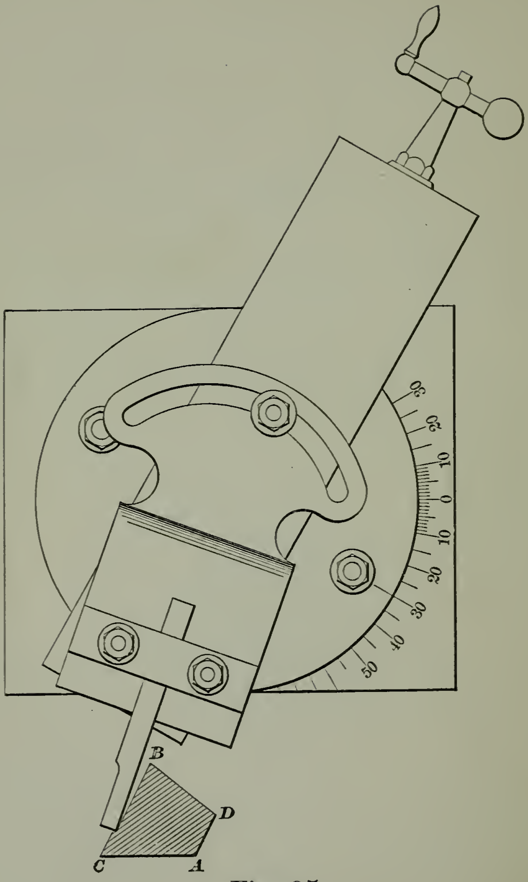


Fig. 85

Chapter X.

Circular Indexing. Straight Line Indexing. Subdividing a Thread.

Circular Indexing consists in dividing a circle into parts. One of the simplest devices for circular indexing is a plate having a circle of graduated lines. A bevel protractor, Fig. 67 or 75, is a graduated device to index to degrees.

Another simple device is a plate having a circle of equally spaced holes, as at W, Fig. 86. The pin P goes into a hole and anchors the plate after indexing. If it is required to index for 24 equal spaces, and there are 24 holes in the circle, the index plate W is moved through one space at every indexing.

In general:

To Index for any number of spaces, divide the number of holes in the index circle by the number of spaces required, and the quotient will be the number of spaces to shift at each indexing.

Example: It is required to divide a circle into 8 parts with an index plate that has a circle of 24 holes.

$\frac{24}{8} = 3$ spaces to move the plate at every indexing.

Another device is a worm and a worm wheel w and W′. The index worm wheel W′ is fastened upon the work spindle and can be indexed with the worm w which is rotated with the index crank C. The whole number of turns of the crank are counted, but parts of a turn are indicated by the holes in the index-plate I. The sector S is set to indicate the proper number of holes, so that they need not be counted after this is set.

If there are 40 teeth in the wheel, and the worm is single threaded, the wheel will turn once around to 40 turns of the worm. To divide 40 spaces in a circle, the worm is turned once at every spacing. To divide into 8 spaces the worm is turned 5 revolutions at every spacing.

In general:

Divide the number of turns of the index crank to one turn of the index worm wheel by the number of spaces required, and the quotient will be the turns of the index crank at every indexing.

Example: In a Milling Machine 40 turns of the index worm, or crank, make one turn of the work spindle; how many turns of the index crank at every indexing for 12 divisions in a circle?

$\frac{40}{12}=3\frac{1}{3}$ turns of the index crank C at every indexing.

Set the sector to indicate $\frac{1}{3}$ of a turn,—any circle of holes divisible by 3 will do;—see table page 125. Count the 3 whole turns and add the $\frac{1}{3}$ turn as indicated by the sector. It should be remembered that there is always one more hole between the arms

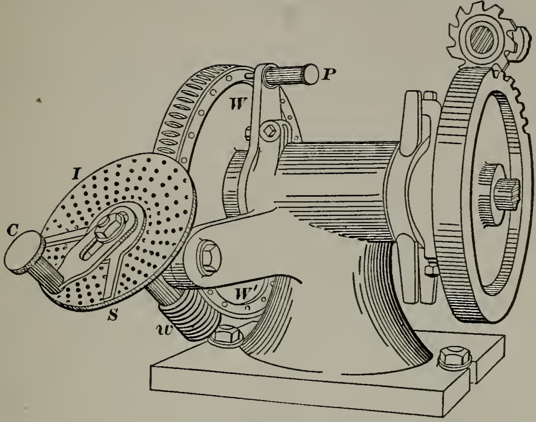


Fig. 86

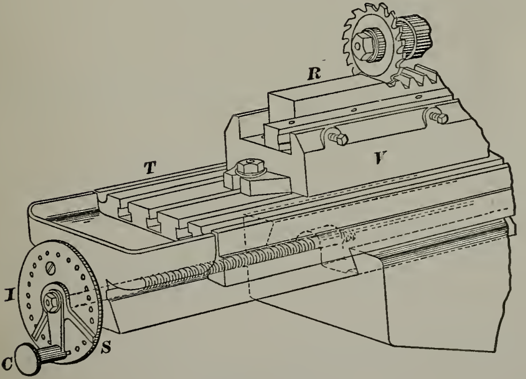


Fig. 87

of the sector, when set right, than there are spaces. Be sure to count the spaces.

Example: How many turns of the index crank at every indexing to divide a circle into 80 parts?

$\frac{40}{80} = \frac{1}{2}$ turn.

How many turns to divide into degrees?

$\frac{40}{360} = \frac{1}{9}$ turn.

When dividing with the circle of holes W W′, the worm w is thrown out of mesh.

A more extensive treatment of the subject of circular indexing is to be found in the Treatise on Milling Machines.

Straight Line Indexing consists in dividing a straight line distance into parts, which is often done with a screw, as shown in Fig. 87. In this illustration a rack R is to be cut. It is held in the vise V upon the table T, which is indexed with a screw that is rotated with the crank C.

Divide the length of the required space by the lead of the screw, and the quotient will be the turns of the screw at every spacing.

Example: How many turns of a screw ¼ lead will index ⅞ inch?

$\frac{7}{8} \div \frac{1}{4} = \frac{7 \times 4}{8 \times 1} = \frac{7}{2} = 3\frac{1}{2}$ turns.

A fractional turn is indicated with the index plate I, and the sector S, the same as in Fig. 86.

Subdividing a Thread. In cutting a multiple threaded screw, the lead is divided into as many parts as there are threads required.

This is merely a case in indexing, and it can be done either by indexing the screw blank in relation to the tool carriage which corresponds to circular indexing, or by indexing the tool carriage in relation to the blank which corresponds to straight line indexing.

Indexing at the Face Plate. A good way is to have means provided at the face plate, to divide into the same number of parts as the screw is to have threads. With two slots in a face plate, one slot exactly opposite the other, a screw can be double threaded by shifting the dog that drives the blank from one slot to the other after cutting one thread groove. With 3 slots, a triple thread can be cut; with 4 slots a quadruple thread, and so on.

Sometimes there is an extra driving-plate held to the face plate which can be indexed to any required number of divisions.

Indexing the Spindle. If the indexing cannot be done at the face plate, the next recourse is with the change gear at the spindle, the spindle being indexed by shifting the spindle gear teeth in relation to the stud gear teeth. If the spindle gear goes upon the spindle direct, and the number of teeth in the spindle gear is divisible by the number of threads required, the required division can be obtained.

Example: A spindle gear, on the spindle direct, has 42 teeth; how many teeth must be shifted in order to cut a double-threaded screw?

$\frac{42}{2} = 21$ teeth to be shifted, which is the same as indexing the spindle a half turn in relation to the tool carriage.

If there is a spindle stud which turns half as fast as the spindle, the number of teeth in the spindle gear, on this stud, must be divisible by twice the number of threads, in order to index at the spindle gear.

Example: It is required to cut a triple threaded screw in a lathe whose spindle stud runs half as fast as the spindle, a 42 tooth spindle gear being on the stud. How many teeth must be shifted in order to index the spindle the required ⅓ turn?

42 is divisible by twice the number of threads; therefore, divide 42 by 2×3 and the quotient 7 is the number of teeth to shift in the spindle gear which is on the spindle stud. $\frac{42}{2 \times 3} = 7$.

It will be seen that any division of 1 turn at the spindle effects the same subdivision of the required lead, no matter what the required lead is.

Indexing the Carriage can sometimes be accomplished by shifting the lead screw nut, and sometimes by shifting teeth in the lead screw gear. In indexing the carriage, its movement is a distance in inches and parts of an inch. Though the movement is sometimes accomplished by rotating the screw, yet the basis of the figuring is a linear distance.

Indexing the Carriage by Shifting the Nut can be accomplished when the difference between one or

more pitches of the lead screw and one or more times the lead of the required screw is equal to one of the required subdivisions. Thus, if a lead screw is 6 threads to an inch, and a screw is to be threaded $\frac{1}{3}$ inch lead double, the carriage can be indexed $\frac{1}{6}$ inch, which is a half of $\frac{1}{3}$ inch, after cutting one groove, by shifting the nut one thread.

A screw $\frac{1}{9}$ inch lead can be cut double threaded by shifting the nut $\frac{1}{6}$ inch, because $\frac{1}{6}$ is one and a half times $\frac{1}{9}$; the difference between $\frac{1}{6}$ and $\frac{1}{9}$ being $\frac{1}{18}$, and $\frac{1}{18}$ is $\frac{1}{2}$ of $\frac{1}{9}$; therefore, in shifting the nut $\frac{1}{6}$, the carriage is indexed $\frac{1}{9}$ and $\frac{1}{18}$ more. In general, a lead can be subdivided either by indexing the carriage only the distance of a subdivision, or by indexing any number of leads and one of the subdivisions more.

Indexing the Carriage by Rotating the Screw. When the lathe is simple geared, and the spindle gear cannot be shifted to index the spindle, the lead screw gear cannot be shifted; because, in simple gearing, shifting the lead screw gear is the same as shifting the spindle gear. Hence, the lathe must be compound geared in order to have the shifting of the lead screw gear teeth available in cases where the spindle gear cannot be indexed.

Divide the required lead by the number of threads and the quotient is the thread pitch, which is the distance to index the carriage to subdivide the lead into the required number of threads. Divide the thread

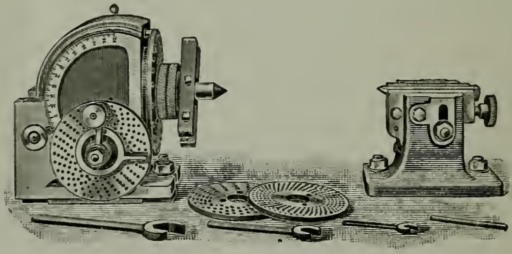
pitch or the distance the carriage is to be indexed, by the lead of the lead screw and the quotient is the number of turns to rotate the lead screw at every indexing.

Example. A screw is to be threaded $\frac{1}{4}$ inch lead, triple, in a lathe whose lead screw is $\frac{1}{6}$ inch lead. How many turns must the lead screw be rotated, after cutting one thread groove?

The indexing of the carriage is $\frac{1}{4} \div 3 = \frac{1}{12}$ inch.
$\frac{1}{12} \div \frac{1}{6} = \frac{1 \times 6}{12 \times 1} = \frac{1}{2}$ turn of the lead screw.

If the lead screw gear is divisible by 2, it can be shifted, or indexed, $\frac{1}{2}$ turn in relation to the stud gear it meshes with.

There are cases in fractional leads that cannot be subdivided either at the spindle gear or at the lead screw gear.



Index Table for Milling Machines.

40 Turns to 1 Revolution.

Division.	Circle.	Turns.	Holes.
2	any	20	
3	39	13	13
	33	13	11
	27	13	9
	21	13	7
	18	13	6
	15	13	5
4	any	10	
5	any	8	
6	39	6	26
	33	6	22
	27	6	18
	21	6	14
	18	6	12
	15	6	10
7	49	5	35
	21	5	15
8	any	5	
9	27	4	12
	18	4	8
10	any	4	
11	33	3	21
12	39	3	13
	33	3	11
	27	3	9
	21	3	7
	18	3	6
12	15	3	5
13	39	3	3
14	49	2	42
	21	2	18
15	39	2	26
	33	2	22
	27	2	18
	21	2	14
	18	2	12
	15	2	10
16	20	2	10
	18	2	9
	16	2	8
17	17	2	6
18	27	2	6
	18	2	4
19	19	2	2
20	any	2	
21	21	1	19
22	33	1	27
23	23	1	17
24	39	1	26
	33	1	22
	27	1	18
	21	1	14
	18	1	12
	15	1	10
25	20	1	12
26	39	1	21
27	27	1	13
28	49	1	21
	21	1	9
29	29	1	11
30	39	1	13
	33	1	11
	27	1	9
	21	1	7
	18	1	6
	15	1	5
31	31	1	9
32	20	1	5
	16	1	4
33	33	1	7
34	17	1	3
35	49	1	7
	21	1	3
36	27	1	3
	18	1	2
37	37	1	3
38	19	1	1
39	39	1	1
40	any	1	
Degrees.			
1	18		2

American Machinist, August 24, 1899.

Chapter XI.

Cautionary. Later Points. In Conclusion.

During the first few weeks it is well for a young apprentice to do his work of a quality about as high as he is capable of doing. After he is sure of the quality of his work, he can have a thought as to the quantity. He should know the parts that are to be accurate; if a part is machined only to make it smooth, there is no need to take time to size it accurately.

Sometimes a workman developes a bent to do all his work as if every part were to be of extreme accuracy, which is likely to consume too much time. Another workman may not pretend to the highest accuracy and yet be able to turn out a goodly quantity of work of a quality that answers all requirements. There is room for both these workmen where work adapted to his ability can be assigned to each.

Some workmen are so efficient as to be able to do both a fine and a coarse job with equal facility; these workmen are highly valued.

It is also a good thing to be able to change quickly from one job to another. If there are

several pieces in a job, some workmen will start a machine on one piece, and, while the machine is running, think out ways to do the other pieces.

If a planer planes hollowing in the direction that the table moves, a common remedy is to block up the bed under the cutting tool. If the ways of a planer bed are hollowing, the work will be hollowing; if the ways are rounding, the work will be rounding. The same principle holds in a surface grinding machine,—a hollowing bed always produces hollowing work,—rounding ways produce rounding work.

In a lathe having a right handed lead screw, if, for a time, short screws are cut near the head stock, the lead screw wears so as to shorten the lead of longer right hand screws cut in the lathe; while long left hand screws, cut in the same lathe, would be lengthened.

If a lathe cuts a lead too short, the lead can generally be lengthened by jacking up the lathe bed in the middle. This scheme lengthens only, and does not correct irregularities.

Our first impression may lead to the opinion that iron, steel and brass are hard and rigid, but these substances are hard and rigid only relatively. A bar of steel an inch in diameter and two inches long may be comparatively rigid, but a bar an inch in diameter and a dozen feet long can be easily bent. Compared to a grain of emery, the ordinary materials used in construction are soft. In fact, the tools we use, as well as every part of a machine, can

be very easily changed in form, and with accurate work we must oftentimes guard against changes.

Effect of Heat. Heat from the hand will crook a straight edge, lengthen a vernier caliper bar, enlarge a standard plug. Sunlight upon one side of a grinding lathe has perceptibly affected the accuracy of the grinding. A screw is lengthened by heat during the operation of threading, so that, if cut the right lead when warm, it will be too short when the extra heat has gone. To thread a screw accurately it is often necessary to cool it off before cutting the last chip. The operation of cutting grooves developes heat in the work and in the machine itself, so that the last groove cut may not be in correct relation to the first. If the machine is stopped for an hour or more the cutter may not track in the last groove cut. If a machine is stopped during any cutting operation, the cut after starting up will not be continuous with that before stopping.

Changes Due to Various Causes. A piece is almost sure to be sprung by cutting it or drilling it in any way, also by driving in a key or a pin.

It is sometimes necessary to peen a piece to true it; if the peening marks are afterward finished off, the piece may spring out of true again.

A piece may be contracted and holes in it made smaller by shrinking a ring on the outside.

When a centre has been out of a spindle, it is not always true when put back again. A face-plate that has been squared up true on a spindle may not be

quite true after having been taken off and put on again.

After a piece has been taken off the arbor it was turned on, it may not be true when placed upon the arbor again; and it is still less likely to be true when placed upon another arbor. If a workman turns an arbor to fit a piece that he did not turn himself, and he finds that the piece does not run true on his arbor, he must not be too quick to decide that the fault is not in his own arbor. There must have been a combination of unusually favorable conditions in the finishing of an arbor, if it really runs true upon dead centres. It is not certain that any angle plate can be replaced true on a planer table, after the plate has been once taken off. The bolting of work against a plate often springs it out of true, and the work as well, so that the work will be inaccurately machined. After V blocks have been taken off a planer table we can not be sure of putting them on again accurately.

While external influences can so easily change nearly everything used in machine making, there are internal influences constantly working changes. We may say that the particles that compose a material of construction are always in motion, and that some particles tend to move in directions contrary to the tendencies of other particles. A hardened steel bar that has been ground true may be sprung out of true by a little heat; and it is more likely to spring of itself than a soft bar.

It is thought that the tendency to spring is somewhat reduced by annealing several times, taking off a chip after each annealing.

It is sometimes well to take off the roughing chips all around, then clamp the work as lightly as is safe and take off the finishing chips.

Let us remember that tendencies to change are always present, that in accurate work we must be always on the watch. Let us have a care also that we do not find troubles that have no existence outside our own minds.

"When you aim at nothing you hit it."

DECIMAL EQUIVALENTS

OF PARTS OF AN INCH.

1/64	.01563	21/64	.32813	45/64	.70313
1/32	.03125	11/32	.34375	23/32	.71875
3/64	.04688	23/64	.35938	47/64	.73438
1/16	.0625	3/8	.375	3/4	.75
5/64	.07813	25/64	.39063	49/64	.76563
3/32	.09375	13/32	.40625	25/32	.78125
7/64	.10938	27/64	.42188	51/64	.79688
1/8	.125	7/16	.4375	13/16	.8125
9/64	.14063	29/64	.45313	53/64	.82813
5/32	.15625	15/32	.46875	27/32	.84375
11/64	.17188	31/64	.48438	55/64	.85938
3/16	.1875	1/2	.5	7/8	.875
13/64	.20313	33/64	.51563	57/64	.89063
7/32	.21875	17/32	.53125	29/32	.90625
15/64	.23438	35/64	.54688	59/64	.92188
1/4	.25	9/16	.5625	15/16	.9375
17/64	.26563	37/64	.57813	61/64	.95313
9/32	.28125	19/32	.59375	31/32	.96875
19/64	.29688	39/64	.60938	63/64	.98438
5/16	.3125	5/8	.625	1	1.00000
		41/64	.64063		
		21/32	.65625		
		43/64	.67188		
		11/16	.6875		

FRENCH OR METRIC MEASURES.

The metric unit of length is the metre = 39.37 inches.

The metric unit of weight is the gram = 15.432 grains.

The following prefixes are used for sub-divisions and multiples: Milli = $\frac{1}{1000}$, Centi = $\frac{1}{100}$, Deci = $\frac{1}{10}$, Deca = 10, Hecto = 100, Kilo = 1000, Myria = 10,000.

French and British (and American) Equivalent Measures.

MEASURES OF LENGTH.

French.		British and U. S.
1 metre	=	39.37 inches, or 3.28083 feet, 1.09361 yds.
.3048 metre	=	1 foot.
1 centimetre	=	.3937 inch.
2.54 centimetres	=	1 inch.
1 millimetre	=	.03937 inch, or 1-25 inch nearly.
25.4 millimetres	=	1 inch.
1 kilometre	=	1093.61 yards, or 0.62137 miles.

OF WEIGHT.

French.		British and U. S.
1 gramme	=	15.432 grains.
.0648 gramme	=	1 grain.
28.35 gramme	=	1 ounce avoirdupois.
1 kilogramme	=	2.2046 pounds.
.4536 kilogramme	=	1 pound.
1 tonne or metric ton 1000 kilogrammes	= =	.9842 ton of 2240 pounds. 19.68 cwts. 2204.6 pounds.
1.016 metric tons 1016 kilogrammes	= =	1 ton of 2240 pounds.

OF CAPACITY.

French.		British and U. S.
1 litre (= 1 cubic decimetre)	=	61.023 cubic inches. .03531 cubic foot. .2642 gall.)American). 2.202 lbs. of water at 62° F.
28.317 litres	=	1 cubic foot.
4.543 litres	=	1 gallon (British).
3.785 litres	=	1 gallon (American).

Table of Decimal Equivalents of Millimeters and Fractions of Millimeters.

$\frac{1}{100}$ m. m. = .0003937″.

mm. Inches.	mm. Inches.	mm Inches.	mm Inches.
$\frac{1}{100}$ = .00039	$\frac{33}{100}$ = .01299	$\frac{64}{100}$ = .02520	$\frac{95}{100}$ = .03740
$\frac{2}{100}$ = .00079	$\frac{34}{100}$ = .01339	$\frac{65}{100}$ = .02559	$\frac{96}{100}$ = .03780
$\frac{3}{100}$ = .00118	$\frac{35}{100}$ = .01378	$\frac{66}{100}$ = .02598	$\frac{97}{100}$ = .03819
$\frac{4}{100}$ = .00157	$\frac{36}{100}$ = .01417	$\frac{67}{100}$ = .02638	$\frac{98}{100}$ = .03858
$\frac{5}{100}$ = .00197	$\frac{37}{100}$ = .01457	$\frac{68}{100}$ = .02677	$\frac{99}{100}$ = .03898
$\frac{6}{100}$ = .00236	$\frac{38}{100}$ = .01496	$\frac{69}{100}$ = .02717	1 = .03937
$\frac{7}{100}$ = .00276	$\frac{39}{100}$ = .01535	$\frac{70}{100}$ = .02756	2 = .07874
$\frac{8}{100}$ = .00315	$\frac{40}{100}$ = .01575	$\frac{71}{100}$ = .02795	3 = .11811
$\frac{9}{100}$ = .00354	$\frac{41}{100}$ = .01614	$\frac{72}{100}$ = .02835	4 = .15748
$\frac{10}{100}$ = .00394	$\frac{42}{100}$ = 01654	$\frac{73}{100}$ = .02874	5 = .19685
$\frac{11}{100}$ = .00433	$\frac{43}{100}$ = .01693	$\frac{74}{100}$ = .02913	6 = .23622
$\frac{12}{100}$ = .00472	$\frac{44}{100}$ = .01732	$\frac{75}{100}$ = .02953	7 = .27559
$\frac{13}{100}$ = .00512	$\frac{45}{100}$ = .01772	$\frac{76}{100}$ = .02992	8 = .31496
$\frac{14}{100}$ = .00551	$\frac{46}{100}$ = .01811	$\frac{77}{100}$ = .03032	9 = .35433
$\frac{15}{100}$ = .00591	$\frac{47}{100}$ = .01850	$\frac{78}{100}$ = .03071	10 = .39370
$\frac{16}{100}$ = .00630	$\frac{48}{100}$ = .01890	$\frac{79}{100}$ = .03110	11 = .43307
$\frac{17}{100}$ = .00669	$\frac{49}{100}$ = .01929	$\frac{80}{100}$ = .03150	12 = .47244
$\frac{18}{100}$ = .00709	$\frac{50}{100}$ = .01969	$\frac{81}{100}$ = .03189	13 = .51181
$\frac{19}{100}$ = .00748	$\frac{51}{100}$ = .02008	$\frac{82}{100}$ = .03228	14 = .55118
$\frac{20}{100}$ = .00787	$\frac{52}{100}$ = .02047	$\frac{83}{100}$ = .03268	15 = .59055
$\frac{21}{100}$ = .00827	$\frac{53}{100}$ = .02087	$\frac{84}{100}$ = .03307	16 = .62992
$\frac{22}{100}$ = .00866	$\frac{54}{100}$ = .02126	$\frac{85}{100}$ = .03346	17 = .66929
$\frac{23}{100}$ = .00906	$\frac{55}{100}$ = .02165	$\frac{86}{100}$ = .03386.	18 = .70866
$\frac{24}{100}$ = .00945	$\frac{56}{100}$ = .02205	$\frac{87}{100}$ = .03425	19 = .74803
$\frac{25}{100}$ = .00984	$\frac{57}{100}$ = .02244	$\frac{88}{100}$ = 03465	20 = .78740
$\frac{26}{100}$ = .01024	$\frac{58}{100}$ = .02283	$\frac{89}{100}$ = .03504	21 = .82677
$\frac{27}{100}$ = .01063	$\frac{59}{100}$ = .02323	$\frac{90}{100}$ = .03543	22 = .86614
$\frac{28}{100}$ = .01102	$\frac{60}{100}$ = .02362	$\frac{91}{100}$ = .03583	23 = .90551
$\frac{29}{100}$ = .01142	$\frac{61}{100}$ = .02402	$\frac{92}{100}$ = .03622	24 = .94488
$\frac{30}{100}$ = .01181	$\frac{62}{100}$ = .02441	$\frac{93}{100}$ = .03661	25 = .98425
$\frac{31}{100}$ = .01220	$\frac{63}{100}$ = .02480	$\frac{94}{100}$ = .03701	26 = 1.02362
$\frac{32}{100}$ = .01260			

10 mm. = 1 Centimeter = 0.3937 inches.
10 cm. = 1 Decimeter = 3.937 "
10 dm. = 1 Meter = 39.37 "
25.4 mm. = 1 English Inch.

SIZES OF TAP DRILLS FOR U. S. STANDARD THREADS.

By the formulas given below, the results, strictly speaking, are the diameters of the bottoms of the threads. The tap drill is, in common practice, the one that is one or two gauge numbers larger, for the smaller, or numbered sizes, and one that is about .005" larger for the larger sizes. The amount allowed for clearance varies in different shops and on different classes of work.

Size of tap drill for U. S. standard thread = outside diameter of screw $- \dfrac{1.299}{\text{threads to the inch.}}$

Size of tap drill for 3-4" screw, U. S. standard thread, 10 threads to the inch $= .750 - \dfrac{1.299}{10} = .750 - .1299 = .6201$, size of tap drill.

Diameter of Screw.	Threads per Inch.	Size of Tap Drill.	Diameter of Screw.	Threads per Inch.	Size of Tap Drill.
1-4	20	.185	2	4 1-2	1.712
5-16	18	.240	2 1-4	4 1-2	1.962
3-8	16	.294	2 1-2	4	2.176
7-16	14	.344	2 3-4	4	2.426
1-2	13	.400	3	3 1-2	2.629
9-16	12	.454	3 1-4	3 1-2	2.879
5-8	11	.507	3 1-2	3 1-4	3.100
3-4	10	.620	3 3-4	3	3.317
7-8	9	.731	4	3	3.567
1	8	.837	4 1-4	2 7-8	3.798
1 1-8	7	.940	4 1-2	2 3-4	4.028
1 1-4	7	1.065	4 3-4	2 5-8	4.256
1 3-8	6	1.160	5	2 1-2	4.480
1 1-2	6	1.284	5 1-4	2 1-2	4.730
1 5-8	5 1-2	1.389	5 1-2	2 3-8	4.953
1 3-4	5	1.491	5 3-4	2 3-8	5.203
1 7-8	5	1.616	6	2 1.4	5.423

SIZES OF TAP DRILLS FOR V THREADS.

Size of tap drill for V thread = outside diameter of screw $- \dfrac{1.732}{\text{threads to the inch.}}$

Size of tap drill for 3-4" V thread, 10 threads to the inch $= .750 - \dfrac{1.732}{10} = .750 - .1732 = .5768$, size of tap drill.

INDEX.